FOUNDATIONS

AND

FOUNDATION WALLS

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FOR ALL CLASSES OF BUILDINGS,

PILE DRIVING, BUILDING STONES & BRICKS,

PIER AND WALL CONSTRUCTION, MORTARS, LIMES, CEMENTS, CONCRETES, STUCCOS, ETC.

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64 ILLUSTRATIONS.

PRACTICAL EXPLANATIONS OF THE VARIOUS METHODS OF BUILDING FOUNDATION WALLS FOR ALL KINDS OF BUILDINGS. TABLES OF THE WEIGHT OF MATERIALS, ETC. THE KIND OF MATERIALS USED, THE LOADS SUSTAINED, AND THE SIZES OF WALL PIERS, ETC. USE OF PILES IN FOUNDATIONS, WITH TERMS, ETC. PLASTERING, MORTARS, LIMES & CEMENTS. EXTRACTS FROM NEW YORK BUILDING LAWS, WITH NOTES.

By GEORGE T. POWELL,

Architect and Civil Engineer, New York.

TO WHICH IS ADDED A TREATISE ON FOUNDATIONS, WITH PRACTICAL ILLUSTRATIONS OF THE METHOD OF ISOLATED PIERS, AS FOLLOWED IN CHICAGO,

BY FREDERICK BAUMAN, ARCHITECT.

Revised and Enlarged by the Addition of much new matter, by G. T. Powell.

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PUBLISHER'S PREFACE.

The subject of Foundations although treated of in various works on construction has not heretofore, with the exception of one or two small manuals, been made the subject of a special book. The importance of the subject and the liberal patronage afforded the first edition of this work had led the publisher to believe a second edition thoroughly revised and brought down to the present date would prove valuable to those engaged in designing and constructing large and important structures. After consultation with the author it was decided to re-cast the whole thing and make it practically a new work. With this in view it has been almost entirely rewritten and all new information bearing on the subject gathered into it.

We regret to say that the author after completion of his manuscript was stricken with paralysis and in consequence unable to give his attention to the revision of proofs. This matter, however, has been very carefully attended to, and we think will be found free from such inaccuracies, ambiguities and misprints as had crept into the first edition. Since the first edition was brought out there have been many important structures in process of construction where the subject of securing foundations was a serious study, among which might be named, the Brooklyn Bridge. The tests made for these structures and other knowledge gained regarding use of cements etc., have been carefully garnered and will be found under their proper headings in the following pages.

On the preservation of timber the author is largely indebted to the researches of Maj. Gen. Cram of the U. S. A., and has quoted largely from his lecture before the Franklin Institute in Philadelphia.

In order to cover the subject more fully than has been done heretofore the author has found it necessary to increase the number of illustrations and very much increase the amount of letter press.

The practical experience of the author and his careful collection of the materials of information on this subject leads us to feel that this book will prove to be a valuable aid to Architects, Builders and Engineers in solving the many difficult problems arising where important structures have to be erected on treacherous soils. Trusting that the same generous patronage will be accorded to it as heretofore we now offer it to the building and engineering fraternities.

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ART OF PREPARING FOUNDATIONS

BY

FREDERICK BAUMAN, (ARCHITECT.)

FIRST PART.

SECOND PART.

FOUNDATIONS AND FOUNDATION WALLS.

CHAPTER I.

Foundations.

The term Foundation is used to signify the bed or bottom of earth, gravel or rock which must be prepared to receive the base consisting of footings and foundation walls. The object to be attained in the construction of all foundation walls is to form solid footings of proper proportion to the superstructure.

Foundations may be divided into two great classes.

First.—Foundations in situations where the natural soil is sufficiently firm to bear the weight of the intended structure.

Second.—Foundations in situations where artificial supports must be provided in consequence of the softness or looseness of the soil. Each of these classes may be subdivided into many kinds under the heading of Engineering works but it is the intention to confine this book more particularly to the foundations of buildings.

Foundation Walls on Soil or Stratum not liable to be affected by Weather, Air or Water.—In building on a natural bottom of this kind, it is necessary to level the surface or footing space, so that the walls or piers may start from a horizontal bed. If irregularities occur in the firm ground, it will be best to fill them up with concrete, rather than to use stone or brickwork. Where some portions of the foundations start below the level of the others, care must be taken to keep the mortar or cement joints as close as possible, or to execute the lower portion of the work in cement or hard-setting lime mortar.

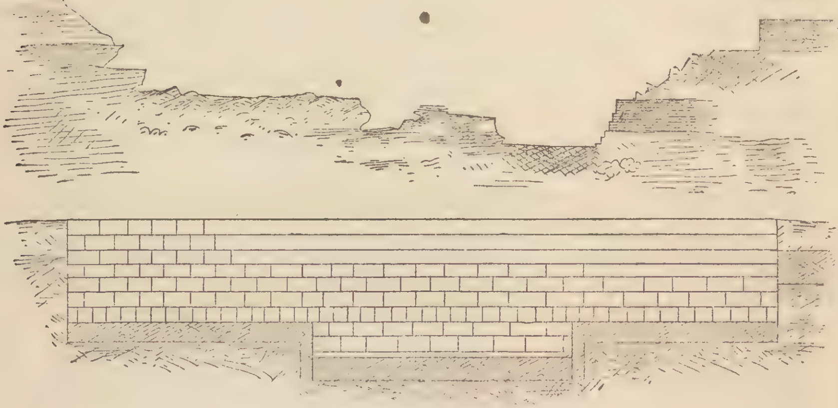
Strong gravel may be considered as one of the best soils to build upon, as it is not affected by exposure to the atmosphere, and is almost incompressible and easily leveled.

While sand resists compression and makes a firm foundation, it must be kept from shifting, or being acted upon by water.

In many cases it is necessary to drive sheath or board piles and use cement.

Rock or partly solid rock bottom requires good judgment and careful handling; for it commonly happens, in the area of a large building, that some portions will rest on rock and others upon clay or loose gravel, and these differences in the character of the soil, are liable to produce irregularities in settlement, and are often difficult to make firm enough to carry the load of masonry uniformly. A common rule, when possible, is to reduce the rock to a certain level, sufficiently deep for the footings, and then remove the soft soil, and make a bed of say three feet of concrete, bringing the concrete to the level of the stone; all of which is explained by the following practical illustrations.

To prepare the surface of stone bottoms of irregular or inclined strata, it is necessary to reduce the stone or brick to level surfaces, thus—(ill. 1 and 2.)



ILLUSTRATIONS 1 AND 2.

or quarry, excavate, and carry the whole to a common level.

Beds of Rock with clay are not very safe without artificial treatment, especially if there are partings or strata of clay, and if they lay in inclined positions. In ill. 3, for instance, when

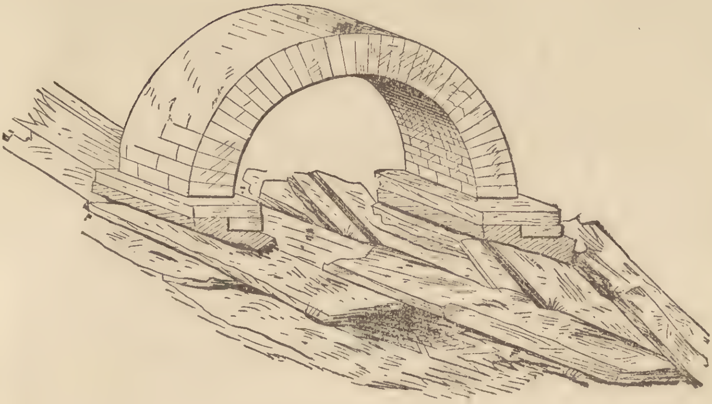


ILLUSTRATION 3.

turning arches, the springing line or base of arch on one side might be secure, while the opposite side would be liable to move from the pressure of the load on the arch; this may be made secure by drilling, and driving iron bars into holes passing through the strata.

Clay.—The most deceptive kind of ground to build upon is clay. Its *insecurity* results from the position of its strata, as well as its elasticity, from being mixed with marl, etc., and its tendency to absorb moisture. In dry seasons it is very firm, while in wet seasons it is elastic and unreliable. It is known that whole buildings have been injured by the moving of clay strata. Of course this insecurity is not likely to occur on level strata or firm clay.

But when the layers of clay are inclined, too much care cannot be observed, especially where the distribution of the load is quite uneven, as for instance in structures where piers, towers, or chimneys occur along with solid walls. It is always well to disconnect towers.

When dry clay rammed around foundation walls becomes wet, it has a tendency to bulge them.

All buildings settle a little, if from no other cause than the weight of the walls and floors.

Shifting clay bottoms that are very insecure have been built upon by laying round timbers, one foot apart, on concrete; the

space between the timbers being laid with concrete, and filled to the top of the logs, to receive stone-slab footings. This method will do on structures of about thirty feet in height, and inexpensive buildings.

The best soils for foundation walls are: gravel and close pressed, hard, sandy earth that will resist the pick—or rock bottom where a horizontal base may be made.

If there is reason to believe that the earth below is yielding it is best in ordinary cases to dig rough wells and fill them with stone to the footings in the cellar bottom; dig say 6 feet below cellar bottom. These wells may be arranged to support walls of 40 to 145 feet in height.

CHAPTER II.

To Secure Solid Foundations in Soft Ground of considerable depth.

In cases of this kind where the expense of building from a great depth to the surface is too great, a number of supports or columns can be brought up through the soft ground, on which to set wall plates of wood, stone or iron for footing courses. There are a variety of ways in which this may be done.

First: By excavating holes through the soft ground, and filling with sand; this is done by boring, or driving down a wooden pile, then withdrawing it and filling the hole with sand. This method is not often used in this country, although if an ample number of holes are filled with sand well packed, a secure foundation may be obtained.

Second.—By driving piles of wood either by hand or with the ordinary steam engine; the piles to be driven until they are firm and secure in the solid earth, and kept from any side movement by bracing with horizontal timber.

Third.—By screwing piles into the soft ground for a bearing. The screw fixtures attached to piles are expensive and are not generally used on city buildings.

The cast or wrought cylinder screw piles are usually from 3 to 8 in. diameter and have at the foot a cast screw with a blade from 18 in. to 5 ft. diameter; they are generally used on docks and railroad work and are screwed into clay, marl or sand by using capstan bars. On engineering works where many of these piles are sunk a special machine is used for the purpose, generally worked by steam. This system of piling is too expensive for buildings and is seldom used except on dock work.

Certain kinds of soft soil have a tendency to stir into a mud batter upon driving piles into them. In this case drive with hand power a few guide piles and then build square or parallel cribs of timber and fill the space with stone closely packed, also

rip-rap stone on the outside securely packed ; in some cases it may be necessary to make a timber bottom secured to the crib. When these foundations are made, test them in several places with bars of pig iron ; cover an area of 10 sq. ft. with a load four times greater than the total load to be borne, including material etc., to each sq. foot of horizontal surface. All calculations for purposes of this kind vary, but the above test will be found satisfactory.

Fourth.—Excavate or make a cutting into the soft bottom and sheath pile with boards braced on both sides and as the excavation proceeds, sink the sheath piles in courses. When sufficient depth has been obtained, fill in with a concrete composed of broken stone, cement and sand.

Fifth.—By sinking hollow cylinders of cast iron or cast iron pipe until they rest upon the bearing strata, removing the soft material from the interior of the cylinder to enable it to descend. If used to resist sea water the iron should be close-grained, hard white metal. This quality of iron is known to have resisted the action of saline salts for at least forty years.

But poor quality of iron is eaten by the salt and soon becomes soft. Large cast iron cylinders from two to five feet diameter are used for pipes. They are usually cast in lengths, say from eight feet to sixteen feet. Short lengths are sometimes connected by internal flanges or lap-joints—the first pile is sometimes provided with a seat, having cutters or a screw fixed with a compression ring after the pile is set.

On buildings this system of piles may be used with advantage for towers, piers, chimneys and heavy structures, but only in cases where simpler methods will not answer.

Boring to test the Bottom.—Boring in common soils or clay to test bottom may be made by a common wood augur of two in. diameter. This will bring up samples of the soil. The iron of the jointed rod should be of the best quality. When the testing has to be made to a considerable depth, it may be necessary to drive down a tube of wrought or cast iron, to prevent the soil from falling into the open hole. These tubes may be in short lengths, for convenience of driving, connected with screw-joints, and the earth may be removed from within by a long

handled scoop. The important object to be attained in using an augur is to learn the character of the underlying strata. An accurate knowledge of which can be obtained only by repeated boring.

Timber Pile Foundations.—Timber piles when partly out of water are objectionable for permanent structures on account of their liabliity to decay. For that reason when they are used for foundations they are cut below the water line. The use of timber piles is very general in New York City and numerous examples may occur to the mind of the reader. We believe this an important subject and will explain the use and manner of driving these piles. First.—We may consolidate the soft or yielding ground by driving piles into it until it becomes so compressed that the piles are prevented from sinking by lateral friction. The usual method is, after the earth has been removed to the depth required, to drive piles from 16 in. to 3 ft. apart as the necessities of the case may require, cutting them off to the level of the water line. A depth of say two feet of concrete is then filled in up to the level of the top of the piles; the hole is then planked over to receive the masonry of the superstructure. Sometimes the planking is laid, not on the piles but on a net

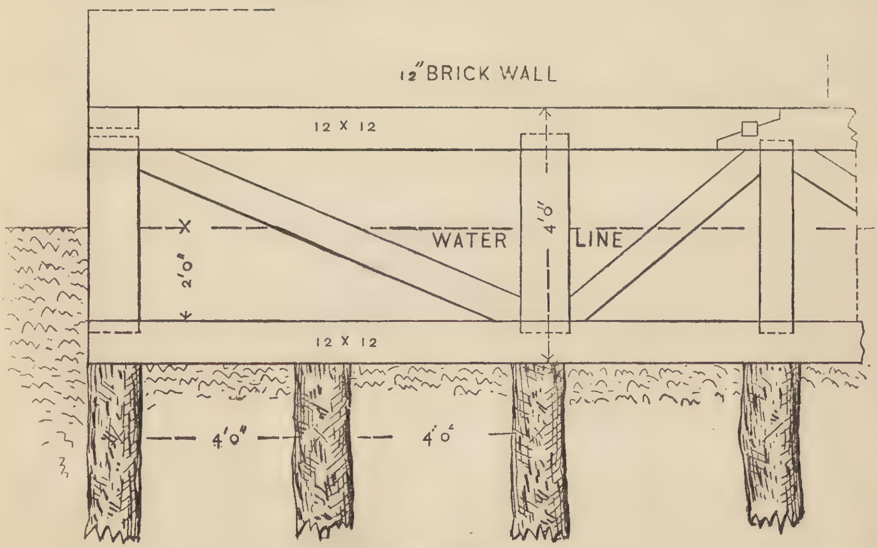


ILLUSTRATION 4.

work of horizontal timber. In timber piling the load is transmitted only in the direction of its length. There are also many cases where stone footings are used and laid directly on the top of the piles; but too much care cannot be taken in a case like this to obtain security.

Illustration 4 shows an elevation of framing on top of piles. This is the plan adopted in the construction of a factory built on the marshes near Hoboken, New Jersey. The building is 50 by 100 feet, and about 20 feet in height. The piles, of yellow pine, were thirty feet in length, and from nine to twelve inches diameter. After being driven, they were cut to a level of two feet below water-line, and spaced for the outside walls four feet to centers. On top of these were placed sills. 12 x 12 inches; on top of the sills were framed uprights, 12 x 12, four feet long, braced from all sides; on top of uprights was placed a second sill, that received a twelve-inch wall. The piles for wooden pillars through center are eight feet to centers. The piles for the chimney and engine-room are about twenty inches apart, with timbers crossing each other, forming a foundation for stone slabs, on top of which is built the brickwork. The foundation of timber is cross-braced from center to outside; and notwithstanding the motion of the machinery, no unequal settling has occurred, although it may have settled one inch before becoming fixed and solid.

Foundations in Quicksand.—

It is not uncommon to find quicksand in New York City. In many localities large masses of sand surcharged with water until it becomes quick are found at a depth of from 5 to 20 ft. In nearly all cases there is a mixture of leaden colored silt or soapstone slime. This is a kind of marl nearly white when it is dry, but when mixed with the sand holds a large amount of water. It is often the case in excavating through quick-sand that strata of this blue marl occurs; it is tough and hard to move but it is utterly unfit for Foundations of any kind. Another difficulty often occurs when layers of cemented clay and gravel are found. It is slow to dig with shovels or picks, and can only be taken out in small quantities, adding greatly to the expense. In nearly all cases where quicksand is found it will be necessary to provide hand or steam pumps with leaders or

gutters, to remove the water. It is useless to attempt the removal of the sand and ooze until the water is drawn off and where any natural drainage can be obtained, channels should be made in every direction possible. It is often necessary in this kind of soil to provide temporary platforms and roadways, while making the excavation, as the disturbance of the soil consequent upon prosecution of the work is liable to make a slough. Where there are large masses of quicksand which are impracticable to remove, owing to locality or surroundings, drive piles, not disturbing the soil more than is necessary, and secure them to horizontal timbers, forming cribs, then brace the whole and fill the interstices with concrete made of broken stone, sand and lime.

One way to proceed to secure footing in this soil is to drive sheath piles on the outside and inside line, leaving the space between to be excavated. Brace the sheath piles adding section after section, as the excavation proceeds. Have prepared concrete enough to fill in each section, proceeding in this way until the work is completed.

Where the soil offers no resistance to sheath pile or brace, construct long wooden cases with sides and bottoms (Caissons) made of 2 or 3 in. boards securely bolted and framed together. Set these in sections and in the position where they are to be lowered ; they are then to be loaded to the top with rough concrete and sunk with their own weight to the depth required. Tests may be made by loading these cases with iron to the average weight, per sq. ft., expected to be borne. The combination of quick sand, marl, hard-pan, etc., found in excavations is often carelessly passed by and ordinary broad footing stones used, resulting in many cases in unequal settling and the ruin of fine buildings. Broad footings of stone are allowable where the soil is not too soft, but two or three courses should be laid with a batter of half their thickness.

To build Foundations on shifting sand.

In speaking of this subject it will be well to state, that the place, condition of sand and the opportunity to secure the bottom of the structure will vary so much that these directions will hardly apply to every case. Excavate an open space in the

sand larger than the base of the structure, lay timber footings, parallel with the line of the walls, cross them with timbers until a solid platform is prepared and pin them together with oak or metal pins. Then make a diagonal cover of say 1 3-4 in. rough boarding, either nailed or pinned; on this platform or deck run sill plates to the size of the frame required and secure them to the timber footings, and on these sill-plates set the corner posts and put in braces; then erect the frame construction as may be necessary for the purpose. This platform or deck will require inclosing sides, thus making a large box to receive the sand. The load of sand will balance and hold in position the whole structure. It is estimated that each cubic ft. of space in a frame structure will average 15 lbs. and each cubic ft. of sand 105 lbs. or seven times heavier than the frame; now if the frame is 35 feet high the box must be loaded with sand 5 feet deep. As an additional security long horizontal timbers with timber anchors may be extended from the bottom of the box. It is important to load the bottom of the structure and place it below the wash of the water. The weight of the sand alone need not equal the weight of the structure provided it is heavy enough to secure the foundations from shifting.

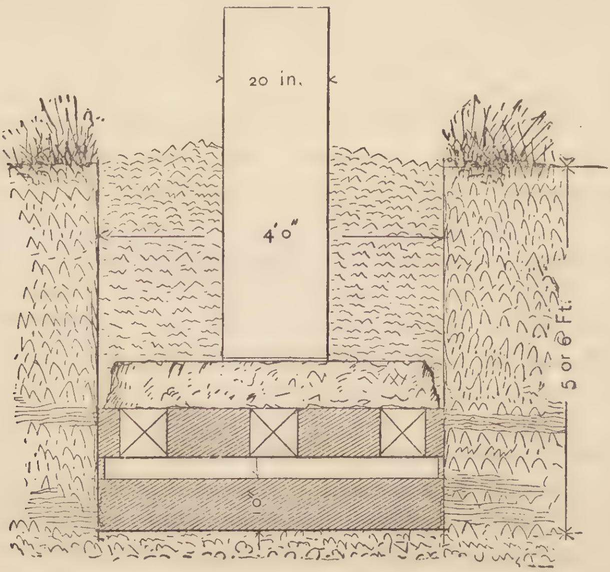


ILLUSTRATION 5.

Illustration 5 represents the foundations of a factory building erected near the edge of the water line in the marshes of Long Island. The soil is a stiff black muck. Trenches were cut through this four feet wide, and averaged six feet deep to a partial quicksand bed. The building is 50 by 80 feet; two stories, 16 feet each; with four feet of brickwork, above ground, to level of first floor. The walls above are sixteen inches thick. After the trenches were dug, a bedding of ten inches in thickness of concrete was laid. On top of this two inches spruce plank are laid crosswise, followed with 8x8-inch timber, laid parallel with the trenches, and the spaces filled in with concrete. On this are laid the base stones, on top of which is built a twenty-inch brick-wall. The trenches on each side of wall were filled up with sand.

This factory has an engine, boiler, machinery and shafting, with an hundred operatives. No settling has occurred.

Structures built on slopes are always liable to slide. In practice this is avoided by cutting horizontal steps in the slope, but great care should be used in erecting the walls to thoroughly bond the stone at all stepping places. Such work should proceed slowly so as to avoid unequal settling as the greater quantity of mortar in the wall on the lower portions of the slope will cause much greater settling there than in the walls on the upper part of the slope and a consequent breaking of joints at the stepping places. The foundations should be leveled in as long sections as possible and the footings carefully laid, especially at the stepping places.

Pile Driving—The usual method of driving piles is by a succession of blows given by a heavy block of wood or iron, called a ram, monkey or hammer, which is raised by a rope or chain, passed over a pulley fixed at the top of an upright frame, and allowed to fall freely on the head of the pile to be driven. The construction of a pile-driving machine is very simple. The guide frame is about the same in all of them: the important parts are the two upright timbers, which guide the ram in its descent. The base of the framing is generally planked over and loaded with stone, iron, or ballast of some kind, to balance the weight of the ram. The ram is usually of cast-iron, with projecting

tongue to fit in the grooves of frame. Contractors have all sizes of frames, and of different construction, to use with hand or steam power, from ten feet to sixty feet in height. The height most in use is one of twenty feet, with about twelve hundred pound ram. In some places the old hand-power method has to be used to avoid the danger of producing settling in adjoining buildings from jarring.

Piles should be driven to sink not more than one inch to the last blow of the hammer. The hammer used should be equal in weight to the pile. The common size of piles is ten to fourteen inches in diameter, and they are driven with hammers or rams weighing twelve hundred to two thousand pounds each. The diameter of the pile should be about one-twentieth of the length.

The present way of driving piles with steam power is very objectionable where permanent structures are to be built, as the severe and frequent jarring is liable to work the soil into a soft mass.

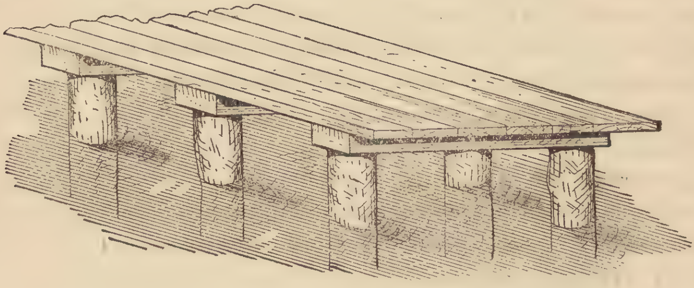


ILLUSTRATION 6.—Piles, &c., showing Water Line.

Terms used in Pile Driving.—A *Pneumatic Pile* is a metal cylinder and is driven by atmospheric pressure, the air being exhausted from within.

A *Hollow Pile* is a cylinder which is sunk by excavation proceeding inside.

A *Screw Pile* has an augur at the lower end, and is sunk by rotation, aided by pressure.

A *Close Pile* is one of whole timber, set close to the others.

A *False Pile* is an additional length added to a pile after driving.

A *Filling Pile* is to fill the space between gauge piles.

A *Foundation Pile* is one for supporting a structure.

A *Gauge Pile* is a preliminary pile to mark the desired course.

A *Guide Pile* limits the field of operation.

A *Sheet Pile* is of half timbers in contact, filling the gaps between gauge piles.

A *Wale* is a horizontal string-piece to bind the piles.

Pile Hoop, a band around the top to prevent splitting.

Pile Shoe, the metallic point.

Test Pile, the first pile driven to test the bottom and should be not less than six inches in diameter.

Size and Kind of Wood for Piles.—Piles are generally round, and from nine to eighteen inches at top, and should be straight and clear of bark and projecting limbs, etc. But where piles are exposed to the rising and falling of tides, for wharves, trestle-work, etc., they are considered to be the best if driven with the bark on. Trees are sometimes selected for this purpose; and when the foliage is full, just on the change, the tree is girdled—that is, the bark near the bottom is separated by cutting it off sufficient to kill the tree, and two or three months later the trees are felled. This method shrinks the bark close to the wood.

White pine, spruce, or even hemlock answer very well in soft soils. Florida yellow pine makes the best for general use but oak, elm and beech for the more compact soils. Piles are generally spaced from two to four feet to centres. Squared piles and tapering ones will not bear equal loads. All should be as near uniform in size as possible.

All timber, driven into the earth, having the common name of piles, may be divided by calling those that stand on solid foundations Posts, and those that depend on the friction of the earth and its constituents Piles, these last require to be considered very carefully for their sustaining power. Although piles may resist the hammer it is sometimes difficult to tell whether the resistance is from having reached a firm strata or is only caused by friction. In such cases always allow a large proportion for safety, and bind the piles together, or brace them. In nearly all calculations that are made for pile driving, the calculations

are based on the soil being *homogeneous*, that is, assuming the soil to be the same kind all the way down. Now this seldom occurs, as there may be alluvium, clay, gravel, marl, shale or pebbles, and some variety occurs in nearly all localities. As it is difficult to find a locality to suit the formula, it is best to accept the judgment of experienced builders, who are experts in this specialty.

The force in pounds with which a pile hammer makes its blows upon the head of a pile is very indefinite, as all the rules differ very much. Correct data may be gathered from actual tests, as follows: In the fine stone London Bridge crossing the Thames each pile sustains eighty tons. They are driven only twenty feet in the stiff blue London clay, and are four feet to centres, and are twelve inches diameter in the middle. This proved too much of a load. At about three feet on centres they would have had only forty-five tons to sustain. Trautwine states that at the Chestnut Street bridge, Philadelphia, the greatest weight on any pile is eighteen tons. Mr. Kneas had the piles driven until they sank three-quarters (.75) of an inch, under each blow, from a 1200-pound hammer, falling twenty feet. Here we have the fall in inches: 20 x 12 = 240 inches, divided by .75 = 320 x 1200 lbs. = 384.000 lbs., divided by 8, = 48.000 lbs., or 21 1-4 tons safe load; but it is best in practice to use only one-half of the estimated safe load.

The refusal of a pile intended to support a weight of thirteen and a half tons, can be safely taken at ten blows of a ram of 1350 pounds, falling twelve feet, and depressing the pile eight-tenths of an inch at each stroke.

Some engineers consider a pile safe for a load of twenty-five tons when it is driven to the refusal of 1350 pounds, falling four feet, not to sink more than four-tenths of one foot under thirty blows. On mud and marsh bottoms it is best not to load the piles more than one-quarter of the above amount.

The following are a number of rules for calculations in reference to the strength and bearing capacity of piles.

To find the Safe Load which the Pile is to Carry.—Given: The weight of ram, the height the ram falls in inches, and the set of pile at last blow, in inches.

Rule—Multiply the weight of ram by the height it falls, and divide the product by eight times the set of pile at last blow.

To find the Height for the Ram to Fall in Inches.—Given: The set of pile at last blow in inches, the safe load which the pile is to carry in cwts. (of 112 pounds), and the weight of ram.

Rule—Multiply the safe load which the pile is to carry by eight times the set of pile at last blow, and divide the result by the weight of ram.

To find the Set of Pile at last Blow.—Given: Weight of ram, height the ram has to fall in feet and the safe load the pile is required to hold in cwts. (of 112 pounds.)

Rule—Multiply the weight of the ram by the height it falls, and divide the product by eight times the safe load which the pile is to carry.

To find the Weight of Rams in cwts. (of 112 pounds.)—Given: The set of pile at last blow in inches, the height the ram is to fall *in inches*, and the safe load the pile is to carry in cwts. (of 112 pounds.)

Rule—Multiply the safe load the pile is to carry by eight times the set at last blow, and divide the product by the height the ram falls.

Pile drivers who are experts know when their piles strike rocks, and sometimes band the tops to prevent them from swaying.

The following are the results of experiments on piles at Fort Montgomery: The piles were twelve to sixteen inches in diameter, and nine to fourteen inches at the smallest end, and were from twenty-nine to thirty-three feet long after cutting; They were of spruce, and weighed about forty pounds per cubic foot, and were driven with a ram or hammer of 1630 pounds, at a height of thirty-five feet. The last blows made them sink from two and a half to six inches. Compressibility of soil about one-eighth of its entire bulk.

Experiments at the Brooklyn Navy Yard.—The piles were twelve to eighteen inches at top, and seven inches at foot; length of piles after cutting averaged thirty-two feet; weight of ram, 2240 pounds, and height of fall twenty-five feet. Average number of blows, seventy-three. They were driven into fine sand, uniform in quality.

In starting all work of pile driving, a test pile, of six or eight inches diameter, should be driven to test the bottom, and of about the same length that it is the intention to drive the Foundation Pile.

A number of piles driven for piers, and a cast-iron cylinder sunk around them, and secured at the top, the earth removed from the inside, and the cylinder filled with concrete, makes an excellent foundation.

Where timber foundations have to be constructed, and the posts or piles of wood are exposed to the rising and falling of tides and sea-water, they are liable to the attacks of wood-boring worms that will destroy ordinary timber in three to five years. One of these is the *Limnoria Terebrans*, and is about three sixteenths of an inch long. These little creatures, assisted by the action of the sea, will soon cut a pile through, as the surface rots rapidly after being perforated by them. The other is the *Teredo Navalis*, and is also known as the ship-worm. It will penetrate the wood from fifteen to twenty-five feet below mean low tide. It is found in most countries. It grows to about three inches long, and one-quarter inch diameter, and has a head like an auger, with the point gone. They leave very small holes where they have entered, which would not attract attention, while inside the wood is completely honey-combed. Their attacks are generally confined to timber above low water mark. Mr. C. G. Smith, C. E., mentions the ship-worm, and gives some particulars about the kind of wood that will remain sound longest in sea-water.

TABLE.

Beach (with Payne's patent process)		10 years, 7 months, first decay.
Teak Wood (East India)		5 years, 6 months, first decay.
English Oak (Kyanized)	5 years, good;	10 years, 0 months, unsound.
British Ash	3 years, good;	5 years, 0 months, unsound.
American Oak	3 years, good;	5 years, 0 months, unsound.
Pitch Pine	3 years, good;	5 years, 0 months, unsound.
Yellow Pine	3 years, good;	4 years, slightly unsound.

It appears that they do not so frequently attack bark, as it kills them before they penetrate. If the outside could be shrunk with heat, slightly charred, and coated with carbolic paint, mixed with Trinidad asphalt, it is thought this would give great pro-

tection. Copper lining has sometimes been resorted to, but this is too expensive for general use. There is an English Silicate Paint used, not readily affected by water; and when there is a covering on the silicate of asphalt of tar and oil, it tends to repel their attacks.

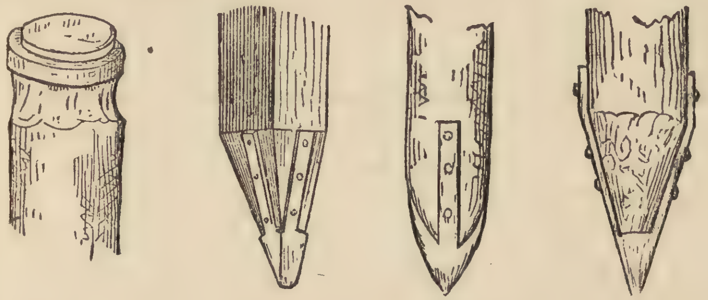


ILLUSTRATION 7.—Wrought or Cast-iron Shoes to Piles.

Another method: All that portion of the pile exposed to the action of sea or fresh water, should have a coat of crude carbolic paint. When this has dried, put on a coat of asphalt hot, and wrap coarse canvas or bagging fabrics spirally around the pile, saturated with hot asphalt; and when this has set, finish with another coat of asphalt hot. After this it is ready to drive. Piles treated this way are not attacked.

Before closing this chapter, I will state that "it is important that every foundation, for either large or small structures, should be prepared to sustain the load of the walls, the materials of the building, and the load to be sustained on each floor." The result of these, added together, gives the load to be sustained (with an average of thirty pounds per square foot on roof for snow). *And the foundations should be made so firm that no doubt will arise about their being insecure.*

In connection with Driving Piles.—It is often found necessary to protect the work above; and paint the iron fastenings. Several kinds of paint are used, lead paint is generally too expensive, and hence the use of Bituminous Paints. A paint made from bitumen, dissolved in parrafine and linseed oil when very hot, has special qualities of durability, and will resist alkalies and acids.—A tar varnish composed as follows is very good: 30

gallons *fresh* coal tar, 6 lbs. tallow, 1 1-2 lbs. rosin, 3 lbs. lamp black, and 30 lbs. freshly slacked lime ; mix and apply hot : When dry, this varnish will receive on its surface any color of oil paint.

Decay and Preservation of Timber, from a Lecture delivered at the Franklin Institute in Philadelphia, Penn., by Maj. Gen'l. Cram, U. S.

Decay and Preservation of Timber.—I have known oak and pine beams, encased in solid brick masonry where hardly any air or moisture could reach, perfectly rotten after eleven years of such imprisonment.

Nor can it be maintained that all kinds of untreated wood exposed to soil, air and water will very speedily decay. The speediness of decay of timber thus exposed will depend upon the kind of wood, the particular acids or salts in the soil, the climate where the timber is to be used, and the thickness of the sticks. To illustrate this, it is only necessary to adduce a few facts which have come under my own observation, also some well authenticated circumstances coming under the observation of other engineers of constructions.

In houses of the old dilapidated town of Chagres, lignumvitæ mudsills were found, after lying seventy-two years upon the ground, perfectly sound. This induced the engineers of the Panama R. R. Co., to replace their first ties, which were of the very best Georgia pine, and which lasted not to exceed three years, with lignumvitæ brought from Darien, at a cost (in 1855) of $ 1.00 per tie. The same Georgia pine taken to a northern climate would have lasted as railroad ties seven years, at least, before requiring renewal.

Red cedar heart in its natural state as fence posts and mudsills has lasted fifty years in the clay and gravelly loam in northern climates without appreciable decay, but in strong lime soil it yields in less time ; while white or yellow cedar will last only from fifteen to twenty years before it will become decayed in a similar exposure and soil.

In the rich bottom lands of Wisconsin, I saw the original massive white oak trunks exhumed as it were from beneath the mucky ground, where they had been upturned by an ancient

tornado, and timber made from them in 1842; the wood was then perfectly sound after an age of centuries, and the timber made from them, used in a construction under cover, is at the present time as sound as ever.

The untreated "redwood" of California, in contact with soil from volcanic debris, I found, on testing its durability, quite as lasting as our red cedar, though it is by no means the same kind of wood. It is weak and brittle; neither is it the same kind of wood as the "mammoth trees" of that State.

I have found our northern red cedar, treated with the old Kyan process, an infusion of corrosive sublimate, after twenty-two years' exposure lying on a slope of strong limy soil, to have gone to decay, especially the lower ends of the sticks, and kyanized white oak of Michigan, resting upon the same kind of dirt, dozed and rotted twenty years after the treatment.

Chestnut railroad ties grown upon the barrens of Maryland, kyanized and laid upon a limy soil some miles north of Baltimore in 1838, I saw tested eleven years afterwards and then perfectly sound, and more solid than when laid; while those of the same kind of wood, untreated, but laid at the same time in the same kind of soil and exposure with the treated ones, lasted only seven years before they required renewal.

This experiment of kyanizing timber was the first, I believe, ever practiced in our country. Ties enough were treated for one mile of track, costing twelve and a half cents per cubic foot of timber. The process, however, was so unhealthy, salivating all the men, it had to be abandoned. It would be worth while to ascertain if those kyanized ties are yet sound. At that time the untreated ties cost only fourteen to sixteen cents.

The original growth of white soft pine of New England, in fence boards untreated and not touching the ground, has been known, after an exposure of more than fifty years, to be free from all signs of decay, while heavy sticks of timber of the same wood and similar exposure were found much decayed in a shorter period. White spruce and red hemlock of that part of our country I found, on examination, untreated, would only last, the former eleven years, and the latter nine years, while white hemlock is more durable than either.

Untreated white oak and white elm piles, which must have

been driven at least forty years, I have found perfectly sound all below and for one or two feet above water, their tops being injured only by abrasion. In these waters there is no need of treating by any antiseptic the timbers to be placed under water.

But for all the horizontal-side, end and tie timbers above the first foot above water, the experience is quite different. As a general rule, I have found these timbers to show decay in seven years after being laid without treatment; and yet many have lain from twelve to fifteen years; but then they have become so rotten as to be blown away by the winds or torn off by the waves. Without treatment, therefore, by some antiseptic we cannot rely upon the timber in these superstructures lasting more than seven years without need of renewal.

In the pier superstructures, we have used chiefly white and hard or red pine and white oak. The vast amount of beautifully shaped timber for the sizes we need, but deemed as too inferior in quality for these superstructures, growing, however, in the vicinity of the lake shores, such as hemlock, white cedar, bass, fir, white and black ash, hickory, white elm, beech, sycamore, etc., etc., are utterly ignored. An antiseptic that would materially, say double or triple the period of decay in these would enable us to bring them into use, at a cost for the untreated timber considerably below that of pine and oak.

The ancient Egyptians must have known of antiseptics for preserving wood. Their old wooden coffins, after 2,000 years, have been brought to light; and a gentleman of much experience in the causes of decay and means of "preservation of wood," has informed me, he "has seen several of these split to pieces, and that the wood (sycamore) was perfectly sound and strong; the wood seemed to have been impregnated with a bituminous substance. The coffins were 'dug outs' from solid blocks of the wood, leaving a hole in the top to insert the corpse, and having a lid carved and ingeniously fitted to enclose the aperture." Now sycamore, as we know it, untreated, is not a very lasting wood. Whether the lost art is to be recovered by the use of modern antiseptics remains to be seen by future generations.

Worms in Wood on Land and in the Open Air.—There is a destructive attack by these upon wood of the trees which have

been cut into logs, out of which timber and lumber are to be manufactured at the mill.

The trees are generally felled, and immediately cut into lengths suitable for these logs, in the winter, and either hauled to the mill during the same winter or rafted to it early in the spring and sawed during the same spring and succeeding summer. In this way the eating by the worm is in a great measure avoided. But if the logs of almost any kind of wood are allowed to lie over the summer on the ground, they almost invariably become eaten unless they are "drossed," which means, to hew off their bark. Peeling the bark of the hemlock in June for tanneries, will prevent the worm in this kind of wood.

If the season, however, is very wet and cold, logs with their bark on are less liable to attack where they lie over; and if they are "boomed," or put into a "log bay" of fresh water, they are preserved from this kind of worm, unless the eggs of the larva are laid in the logs before they can be put into the water, in which case the larva are known to develop into the living worm in six months after sawing and sticking up the stuff, which, though apparently free from the worm when piled, soon becomes greatly injured, as many a pile of supposed valuable timber has shown.

When a thrifty tree, however, is overturned by the roots and, after dying, cut into saw-logs or hewn, no worms will be found in the wood.

Some of the very best lumber comes from wind-falls after the trees have been dead for years, taking care, however, not to sever the rooty mass from the trunks while green. These facts led to the explanation of the manner in which these worms are produced in saw-logs and green timber recently felled by the axe. A small insect easily penetrates by the ends of the green log along through its whole length in the palatable juices between the dark and sap wood and deposits her eggs, which very rapidly develop into eating worms. No doubt there are various kinds and sizes of these preying upon wood, and among which may be classed the ants, which are so destructive to wood in tropical climates.

A wind-fall, with its up-turned roots having earth attached, affords no access to the insect; and when the green logs are "drossed," there is no bark shelter for the insect which dreads

the water so much that it will not enter the logs after an immersion in fresh water.

It seems to me that if the lumber manufacturer has the ill luck of being compelled to allow the green logs to lie over on the ground, the besmearing of the ends with some cheap bad smelling paint might prevent the access of the insect.

Worms in Wood under Sea-water. — These, I have observed, on our sea-coasts, seldom work upon piles and dock-facing timbers, except in those parts standing between half ebb and half flood tides; in the space between these two planes, however, their operations are indeed wonderful and dreadfully destructive. On some of the European coasts, I think they range in their attacks from extreme low to nearly high tide.

It is not very many years since it was believed these worms could only exist in the tropical climates, and that they were only known in cold climates by being brought in vessel bottoms. But this was an illusion which experience has since dispelled.

As far east as Castine Harbor, Me., they began destroying piles and other dock timbers of the best white oak, and so effectually did their work that renewals had to be made. It is believed they were introduced there from old worm-eaten vessels coming home and lying to the docks until the vessels no longer afforded substance for boring, then the worms forsook, and resorted to the piles and dock timbers. No oak has for years been used there for the renewals. Yellow pine is used, and as long as the resin remains in the wood, it is comparatively free from the worm; but after a few years, the resin becomes washed out, then the worms commence the havoc in good earnest.

In various places on our Atlantic coast from Maine to Mexico, and on our own Pacific coast, this annoying and costly evil exists. There, I have observed, no vessel or wood structure, except as high up as about where the fresh water and the tide water meet, is safe from this evil. The remedy of covering the exposed parts with the sheet copper is only effectual until the sheathing becomes punctured, torn, or abraded off, then the worms immediately enter.

In the bay of San Francisco, the worms are very active and produce great havoc. They bore deep into the piles and dock timbers, leaving hardly any part within their range unperfor-

ated, but the tubular track of one never pierces across the tube bored by another worm. Their instinct teaches them scrupulous respect for each other's way. In a period of less than four years they will destroy the piles. And there are worms that wield their mandibles with such extraordinary power as even to bore into solid rock.

In the lower part of the Sacramento river, just above where it enters Suisune Bay, the banks at low tide expose all along for one or two miles innumerable hard, compact sand-boulder rocks. In carrying a military survey along these banks, I observed in hundreds of the rocks deep tublar holes of from one-half to three-eighths inch in diameter, running straight in, some to the depth of eighteen inches. Every hole was lined with a perfect coating of beautiful white enamel as hard as glass. At the bottom of each hole there was invariably a worm found, who had bored for himself a habitation into the rock. These extraordinary mandibular worms, if not the same kind, are about the same size, I judged, as the smaller kind of salt water borers called *limnoria.*

The piles used in the San Francisco waters, are chiefly Oregon spruce and Oregon pine. An antiseptic that will preserve wood there will not fail to be favorably received.

New processes for preserving timber are being constantly introduced. Prof. Chas. A. Seely and W. T. Pelton are the patentees of some processes.

The method of application patented by Professor Charles A. Seely, of New York, in 1867, is a modification of, and an undoubted improvement upon Bethel's process, in being applicable to green, water-logged wood, and with far more efficiency even to seasoned wood, differing materially, however, in the mode of application of the dead oil, This new process consists of immersing the wood in a closed iron tank of the oil, raising the whole to a temperature between 212° and 300°F. This action is allowed to go on until the moisture or water contained in the wood is expelled, or has escaped in the shape of steam. The water being supposed thus expelled, and the pores containing little or no steam, the hot oil is suddenly replaced by a bath of cold oil, condensing all the remaining steam, and thereby leaving a total or partial vacuum in the wood cells, into which the

oil immediately rushes, impelled by the hydrostatic pressure of the oil, and the pressure of the atmosphere, favored also by capillary attraction.

Those who favor this process claim for it the following results:

1st. The effect of the hot bath is to sufficiently season the wood, and destroy or coagulate all the albumen and expel the water and other fluids from the pores.

2d. The effect of the cold bath is to impregnate the wood cells with the antiseptic (carbolic acid), and at the same time stuff, as it were, the pores that will for a long time after exposing the timber to the air, variations of atmospheric temperature, soil, rain, salt or fresh water, resist absorption of destructive agents from all these sources, the borers in salt water, worms on land, and white ants in tropical climates inclusive; and also prevent the rusting of iron bolts, spikes, nails, etc., that may be driven in the treated wood.

CHAPTER III.

Excavations.

Under this heading it is thought best to give abstracts of a revised ordinance of New York City, relative to the Construction of Vaults (similar laws in reference to vaults and areas should exist in other cities) with the rates to be paid on permits, *i. e.*:

"A permit must be taken out before excavation, or legal proceedings will be instituted against the owner or builder."

"SEC. 1. Empowers the Department of Public Works to grant permits for the construction of vaults in the streets, provided, in their opinion, no injury will come to the public thereby.

"SEC. 2. Forbids the construction of vaults in any street in the City of New York without permission in writing from said board, under the penalty of one hundred dollars.

"SEC. 3. Applicants for permits must state the name of the owner of the premises in front of which the vault is to be built; the purposes for which the building is or is intended to be used; the number of square feet to be occupied by the vault, including its walls; and the proposed length and width of the same.

"**Rule required to be complied with:** — When applications for vaults are made, such applications shall in all cases be accompanied by a plan drawn upon a scale of one-fourth of one inch to one foot, showing the whole area to be built, including walls, and designating the open area, if any, and also the space to be exclusively used for stairways (see Sec. 15); and in case there shall be any fire hydrant in front of premises where the vault is to be excavated, the position of such hydrant shall be shown on such plan, and there shall be a space of two feet left around the hydrant.

"SEC. 4. Requires that payment for each square foot of ground to be occupied by the vault shall be made on obtaining the permit, under the penalty of one hundred dollars.

"SEC. 5. Prohibits the construction of vaults beyond the line of sidewalks or curbstone, under the penalty of two hundred and fifty dollars. *It is to be distinctly understood* that the permit gives no authority, and it is strictly forbidden, to disturb, by excavation or otherwise, any water hydrant, or stop-cock, or stop-cock chamber, or water pipe; or do anything to prevent the proper use of any hydrant or stop-cock, or expose them to freezing.

"SEC. 6. Makes it the duty of the person obtaining a permit to deliver to this board a certified measurement by one of the city surveyors of the ground occupied by the vault before the same is covered, under the penalty of one hundred dollars.

"SEC. 7. If it appears by such certificate that the vault occupies a greater number of square feet than shall have been paid for, the owner of such vault, and the master builder under whose direction the same shall be constructed, shall, in addition to the penalty imposed in and by section 4, severally and respectively forfeit and pay twice the sum previously paid, for each square foot of ground in excess of the number of square feet previously paid for.

"SEC. 10. During the time of constructing vaults a lamp or lantern shall be kept burning the whole of every night, which shall be placed so as to cast its light upon the opening, under the penalty of ten dollars.

"SEC. 11. All vaults must be completed and the ground closed over them within three weeks after they are commenced, under the penalty of five dollars for each day they may remain uninclosed after that period.

"SEC. 12. No area in the front of any building in the City of New York shall extend more than one-fifteenth part of the width of any street, nor in any case more than five feet, measuring from the inner wall of such area to the building; nor shall the railing of such area be placed more than six inches from the inside of the coping on the wall of such area, under

the penalty of two hundred and fifty dollars, to be recovered from the owner and builder thereof severally and respectively.

"SEC. 14. Every description of opening below the surface of the street in front of any shop, store, house or other building, if covered, shall be considered and held to be a vault within the meaning of this chapter, and the master builder, or owner, or person for whom the same shall be made or built, shall be liable to the provisions, payments and penalties of this chapter severally and respectively.

"SEC. 15. The last preceding section of this chapter shall not be constructed to refer to those openings which are used *exclusively* as places for descending to the cellar floor or any building or buildings by means of steps.

"Payments for vault permits must be made on taking out the permit, as follows, viz.:

"For permission to construct a vault in front of any building, seventy-five cents per square foot.

"Where it is proposed to increase the superficial area of any vault, the increased area is only to be paid for at the above rates. In such case the surveyor certifying to the dimensions of the new vault must also certify to the dimensions of the old vault.

"It will be seen by section 14 that excavations commonly known as areas or parts of areas, if covered, are to be paid for as vaults, excepting such space only as may be occupied by steps for descending to the basement or cellar floor."

The preceding laws in reference to vaults and areas are very effective in New York, and similar laws should exist in all cities to protect the owners of property, pedestrians, vehicles, and business generally during the construction of buildings.

A further permit is required before excavation and the commencement of work in the foundations. This permit has to be obtained from a Board known as the Department of Buildings in the City of New York. Some other large cities in the United States have Department of Buildings or some laws that strictly pertain to buildings. The requisite information in regard to the New York laws on this subject will be given under the heading of Walls, etc.

Excavations. — Twenty-four cubic feet of sand; or, seventeen cubic feet of clay; or, eighteen cubic feet of earth; or, thirteen cubic feet of chalk, equal one ton. One cubic yard of earth before digging will occupy about one and one-half cubic yards when dug, and contains twenty-one struck bushels, and is considered a single load; or, double this a double load.

Footings and Footing Courses. — In commencing the erection of any building it is usual to spread the bottom courses of the masonry beyond the inner and outer face of the walls; the spread courses are termed footings, and distribute the weight of the structure over a larger area of bearing surface; the liability to vertical settlement from the compression of the ground is greatly diminished.

In the case of isolated buildings standing on a small base, they give a great protection and resist the force of high winds, storms, etc.

For instance, take the case of a chimney shaft one hundred feet high, standing on a base ten feet square, and exposed to heavy gales. The compression of the ground from the force of the wind that would cause a depression of one-quarter of one inch, would cause the chimney to be out of centre five inches. If the base is increased to twenty feet square, we not only increase the leverage to resist the force of the wind, but the sustaining surface is quadrupled; so that the resistance is eight times greater than in the first instance. Footings, to be effective, must be bonded into the body of the work, and of sufficient strength to resist the cross-strains to which they are exposed. It is a common practice among mason builders, whether the materials be of brick or stone, to simply comply with the requirements of the plans, lay the footings down, pay no regard to bonding, and leave the unequal settlement of the walls to chance. This, of course, does not occur with men skilled in their trades.

In Building large Chimneys for Manufactories, the size of the chimneys and the height should be determined by proper experts, and with the opinion of the Engineers.

Rules for Chimneys:—The area of the chimney should be three-quarters that of the opening over the bridge; viz: one and

one-half inch per pound of coal consumed ; or, nineteen and one-half inches for each foot of fire surface burning thirteen pounds per hour. The whole diminution of flue should be gradual, and not by any offsets. A common rule for size of chimneys is, that the minimum area of chimneys twenty-four to thirty yards high is four hundred square inches for each twenty horse power.

Chimneys of any considerable height should be tied, clamped, or anchored with wrought iron straps, etc., at not less than every twenty-five feet in height.

The highest chimney stack in England is at Bolton ; it is 367 feet taken from the surface of the earth, octagonal in plan, 14 feet on each side, and 112 feet girth at bottom. Thickness of brickwork at bottom, 8 feet ; thickness of brickwork at top, 1 foot 6 inches ; 5 feet 6 inches on each side at top, or 44 feet girth. The top is finished with stone.

The chimney of the Edinburgh Gas Works is 341 feet 6 inches high. It is 329 feet from the surface of the earth. Stone foundations 40 feet 6 inches, by 6 feet 6 inches deep ; 30 feet square at ground line, 27 feet 9 inches square at top of stone pedestal ; on top of this the brick shaft is 264 feet high ; 26 feet at the bottom diameter, and 15 at the top.

In the construction of large chimneys, and particularly isolated ones, they should be built with great care, the mortar being prepared every day, of one of lime to two parts of sharp sand ; or, of cement and sand. The masons should change positions and level and true the work often, to equalize the difference in the work done by different men ; select competent men for the work.

The Foundations and Trenches for Footings should be cleared of all rock, rubbish or soil, and leave the site of the intended building clear and unincumbered ; and make perfectly level and hard the bed of all trenches, and consolidate the earth about the same.

Foundations in cities are usually excavated according to the survey furnished by one of the City Surveyors. Outside of the city, for suburban or country buildings, the excavations are generally made direct from the plans. After the earth is removed, either in city or country, it is necessary to lay out the base-walls

of the structure with lines, secured to stakes driven in the ground. The common method is to establish one line, call it a *base* line, running parallel with the street line curb or fence line, as the case may be. From this, where no side-walls control the lines of the building, it may be necessary to produce a line square, and at right-angles to the *base* line, which is usually done thus: * Draw the line tight, and as near a right angle to the base line

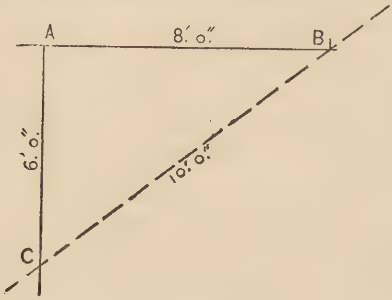


ILLUSTRATION 8.

as possible; then true it by using a rod laid off in feet. After you have commenced, and have a long line to square, it may be necessary to increase the triangle in laying out to twelve feet, sixteen feet and twenty feet. After this the square may be tested on the lines by using a rod thus:

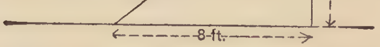


ILLUSTRATION 9.

Take any angle, *A*, *B* and *C*, on one side with three measurements, and try the same on the other side. This has to be tested very carefully. Some masons have large wooden squares

* A Leveling Instrument is now manufactured especially for this purpose.

for the purpose, the use of which is better than deciding by sight, or even measuring on the line.

Another method of getting a right-angle: To erect a perpendicular line at any point on the base line *A B*, set one point of compass or rod to sweep a radius at *B*, and describe the arc of a circle; use the same radius, and put one point at 1, and intersect the line at 2, then produce a line from 1 to 2. Use 2 as a centre of same radius, and draw a curve, then produce and con-

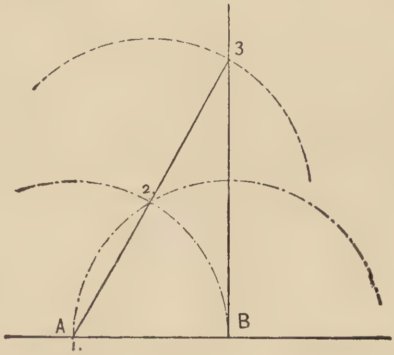


ILLUSTRATION 10.

tinue the line 1 to 2 to 3. Then draw the line from *B* to 3, and this gives the desired angle. After this is done once or twice, it is very simple. Circles, polygons or ellipses are best when laid out on a wooden template.

It is best in laying out lines for excavations to set the stakes at some distance from where the earth or debris is being removed, and to test the exact angles, by diagonal measurement:—This must be done accurately even if a little more time is required; as soon as this is done it is important to establish the grade line.

To make a right angle or perpendicular line: Divide the given line A, B, into two equal parts, and draw a perpendicular line as shown on the illustration No. 11. From the points A and B as centres and with any radius greater than one-half A B describe the two arcs C and D, then draw a line through E to F. The line E F will be at right angles to A B. This may be used where it is necessary to lay out a large square or lines for centres.

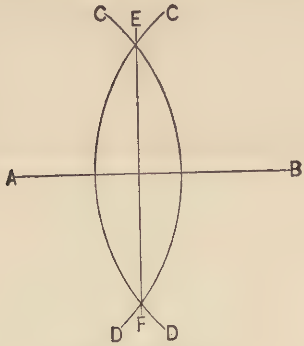


ILLUSTRATION 11.

To draw an Octagon in a given square. From each corner of a square, and with a radius equal to half its diameter A to B, describe the four arcs; and join the points at which they cut the corners of the square. Illustration 12.

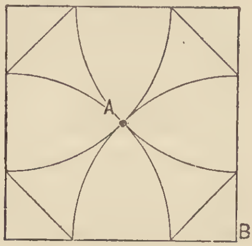


ILLUSTRATION 12.

Springs in Cellars, etc.—After excavations are made for a building, either in city or country, there is often found a small water-course or spring. In the country it is best to tap the spring or line of water-course outside of the building, and take it away from the building, and follow a course that will prevent its returning and undermining the walls. In cases where this cannot be done in the city or country, sink and build with rough stone such size cistern as may be required for a flow of water for three or four days, and carefully build a drain from cistern, following the line of water-course to outside wall, if possible.

If there is an overflow liable to occur from freshets, tides, rain, etc., and the cellar bottom is below the line of sewer, it may be considered the best to build cemented cisterns that will

fill to a certain height and have an indicator to prevent overflow or rise of water. These may be emptied by using a small force-pump.

If a cellar bottom is located in low ground, or below adjoining cellars, and a supply of water seems to permeate the soil, and accumulate, it is not safe to use any steam-pump, as it may draw water from the surroundings, and weaken the foundation walls, unless due precaution has been taken in building. Ordinary cisterns and hand-force pumps seem to act the best in such cases, by pumping water into a waste-pipe to be carried into sewer. If there is no waste-pipe, then it has to be pumped to such height that it may be emptied. Where a large spring or water-course is found on the cellar line of large structures, it is necessary to collect by drains all the water into a cemented cistern, and attach to the engine used in building a small pump of sufficient capacity to keep the water below a fixed line forty-eight hours, to prevent an overflow.

As a rule the surface of cellar bottoms should be covered with concrete, ranging from four to twelve inches in thickness, to form a smooth floor surface. Those that are wet or damp (and nearly all are more or less so) should have a layer of asphaltum over the surface, and extended up the sides to a point above where the dampness arises (see illustrations 36 and 38). The asphaltum, when used, should be protected by laying on it a course of bricks, bedded in cement, or an additional layer of cement. If a smooth, handsome surface is desired, Portland cement should be used for the finish. Rosendale and many American cements of the best quality may be used, and bricks coated with asphaltum are often used.

CHAPTER IV.

FOOTINGS — STONE AND BRICK. STRENGTH OF STONES AND METHODS OF OBTAINING SECURE FOUNDATIONS.

Stone Foundations, Walls.—The bottom stones of course sustain the load or weight of the building, and hence the greater the risk arising from any irregularities in the bedding of the stone. To avoid this, the stone should be dressed true, no spalls used, and properly bedded. In New York City the foundation or base stones—nearly all of which come from quarries on the island—are of Gneiss, a kind of granite, which crops out above the surface in irregular strata. The others are common building stone, and a blue kind of limestone.

No back joints should be allowed beyond the face of the upper work, except where the footings are in double courses, and every stone should bond into the body of the work several inches at least. Unless this is attended to, the footings will not receive the weight of the superstructure and will be useless. See Ill. 13.

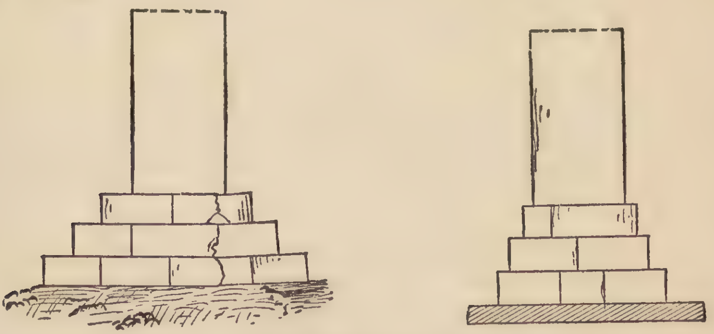


ILLUSTRATION 13.

In fixing the spread of the footings or foundation courses of the masonry or brick-work of ordinary walls the usual rule is to make the breadth of the base one and one-half the thickness of

the body of the wall on compact gravel, and twice that thickness on sand or stiff clay.

The following principles should in all cases be observed in the building of all kind of stone masonry: To build the masonry as far as possible in a series of courses perpendicular to the direction of the pressure they have to sustain; avoid all continuous joints and break-joints; use the largest stones for the foundation courses; lay all stones with layers or beds so that the pressure will act directly perpendicular to the direction of the layers; *i. e.*, by laying the stone on its *natural bed.* This is of primary importance to strength and durability.

Moisten the surface of dry and porous stone before bedding it, which prevents the mortar from drying too fast, and being reduced to powder by the stone absorbing its moisture. Fill all the joints and all spaces between the stones with mortar; have such spaces as small as possible.

Stone-work is estimated by the perch of twenty-five cubic feet, or by the cubic foot.

Brick for Foundation Footings, etc.—The following are the principles to be observed in building with brick:

First. Reject all bad shaped and unsound bricks. Good bricks are regular in shape, with plane surfaces and sharp, true angles. They give a clear ringing sound when struck. When broken, they show a compact, uniform structure. Should not absorb more than one-fifteenth their weight in water.

Second. Place the beds of the courses perpendicular to the pressure which they sustain. Make the bricks in each course break-joint with those of the courses above and below, by overlapping from one-quarter to one-half of the brick. Cleanse the bricks, wet them thoroughly before laying to avoid absorbing the moisture in the mortar too rapidly. Fill all the joints with mortar, taking care that the mortar shall not exceed one-quarter of one inch in thickness; lay four courses to ten inches, or four courses to twelve inches, accordingly as you use different thicknesses of brick, and then only allow one-quarter inch for each joint. Use no bats or pieces of bricks.

The volume of mortar required for good brick-work is about one-fifth of the volume of the bricks.

English bond (Illus. 14) in brick-work is considered the strongest. It consists in laying entire courses of headers and stretch-

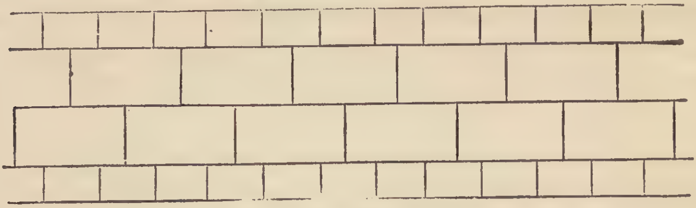


ILLUSTRATION 14.

ers periodically; the proportion here shown is one course of headers to two of stretchers.

In ordinary walls it is usual to lay one course of headers to four of stretchers. Flemish bond in brick-work is a header and stretcher laid in each course; thus: (Illus. 15.)

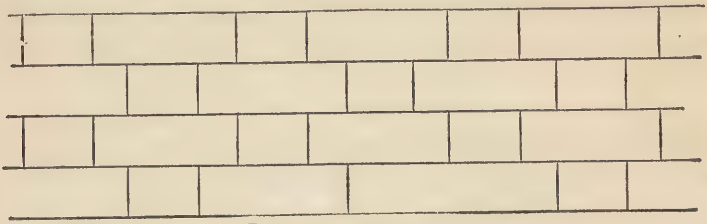


ILLUSTRATION 15.

This presents a very neat appearance, but it is not considered as strong, where a question of strength arises, as the English bond.

In building a factory chimney the longitudinal tenacity is more important than the transverse; and it is best, in cases of this kind, to have four stretchers to one of headers.

Brick-work is estimated by the thousand, and also by the cubic foot. Walls vary slightly in thickness, owing to the sizes of the brick; but the superficial quantity is the same.

TABLE OF BRICK-WORK.

8 or 9	inch wall,	1	brick thick,	14	bricks	to the	superficial	foot.
12 or 13	"	"	1 1-2	"	"	21	"	"	"	"
16 or 18	"	"	2	"	"	28	"	"	"	"
20 or 22	"	"	2 1-2	"	"	35	"	"	"	"

The best Philadelphia and Baltimore bricks are eight and one-

half inches long by four and one-quarter inches wide, by two and one-half inches thick.

The Baltimore front and wall brick is the same size as the Philadelphia. The average size New York brick is eight inches in length, four inches wide, and two and one-quarter inches thick, and is mostly made up the North River. Inferior grades of brick are made eight inches lóng, three and one-half wide, and two and one-half thick, and some of them sold in the New York market are unfit for sound walls. The Croton North River brick measures eight inches by three and three-quarters wide, by two and one-quarter inches thick; average when laid, four courses, including mortar, to ten inches. The very handsome white brick for ornamental purposes, from Perth Amboy, is eight and one-quarter inches long, four and one-eighth inches wide, and two and one-quarter inches thick. The Trenton, New Jersey brick is eight and three-eighths inches long, four inches wide, and two and three-eighths inches thick. The Enameled-faced bricks made in New Jersey are buff, brown, black cream, and blue in color, and are eight inches long, four inches wide, and two and one-half thick. Hollow burned brick, used for hollow brick walls and inside firring of various sizes, are:

Single,	8 inches	long,	3 5-8 inches	wide,	by	2 1-4	inches	thick;
Double,	8 "	"	7 1-2 "	"	"	4 1-2	"	"
Treble,	8 "	"	7 1-4 "	"	"	7 1-4	"	"

Hollow arch bricks are about 7 1-4 x 7 1-4, beveled for arches, and of various sizes.

Use of Stone for Building Purposes.—"M. Viollet-le-Duc has told us how the mediæval constructors made it a rule to place stone upon their beds; how in buttresses, arches, and vaulting of different kinds the stones were so laid as to receive the thrust obliquely or laterally upon their beds; and how they employed only certain stones capable of great powers of endurance which are less easily delaminated—i. e. liable to scale off in layers—when so fixed. About thirty years ago the late Mr. C. H. Smith, who had thoroughly studied the subject of lithology, said that the importance of laying stones in buildings upon their beds was generally over-rated, and that it signified little which way a stone was laid unless it presented a decidedly laminated structure.

We unhesitatingly maintain that soft, calcareous or limestone should be laid in the walls of a building upon its natural bed, and that the beds should not be exposed to inclement weather after they have been dressed.

It is by no means certain that porous stones are inferior because of their porousness.

If stone easily soaks up water it also easily ejects it. Dampness attacking a stone wall from the outside is infinitely less destructive than that which attacks it from the inside. Provided the action be free from the outside to the inside and not from the inside to the outside of a stone the moisture does not seriously injure it. Soft stones for years impregnated with dampness have not decomposed even though laid in the basement walls of a building. Certain stones which decompose after exposure to the air remain intact in water or damp earth. Stone is much more likely to decay in damp and sheltered situations than when it is exposed to the full action of atmospheric influences; but this should be "read between the lines" because in damp situations stone is not always subject to decay. If the exposed face of the stone dries and leaves the heart of the stone unnaturally wet the internal moisture will ultimately crystallize upon the surface, and during this process a certain amount of decomposition will take place in the stone itself.

But if the stone be so placed as to permit the moisture it has received from the outside to be drawn away from it in a fluid state its component parts will not suffer vital deterioration.

Limestones suffer quick deterioration when placed next to certain sandstones. Various kinds of lime and cement eat into soft calcareous stone, which, besides, contains within itself the elements of its own destruction; and dampness insidiously admitted will set in motion these elements of change which in a latent state are harmless.

Rondelet—totally ignoring the fact that in architecture people prefer to spend as little money as possible except on external show—advises, under similar circumstances, the use of scintillant or ignescent stones, i. e. those which emit sparks of fire when struck with steel, because they effervesce on the application of the principle acids; some kinds however will resist the action of fire. Calcareous stone is that which is the most abun-

dantly found upon the surface of the globe. It is homogeneous, easily quarried and wrought and it adheres to mortar. It is perfectly well known that under certain acids, even vegetable acids, these calcareous stones effervesce and disintegrate ; and that under the action of fire they are converted into quick lime and carbonic acid. It has also been observed that a species of spider, microscopic in size, is a fertile agent of destruction. These insects spin their webs in the almost imperceptible cavities which abound in limestones ; dust rests upon them and moisture of all kinds is thus attracted, and this, with the incessant labours of the insects themselves, is one of the causes of deterioration. (This does not often occur in this country.) We have still to allude to an important fact connected with stone of nearly all kinds. A natural action takes place in the majority of limestones immediately upon their extraction from the quarry and exposure to the air. This action, which in most cases is vital in its effects and certain in its results if properly encouraged, should not be ignored by architects and builders. The half hard and soft stones harden after their extraction.

All calcareous stones originally contain a certain quantity of water which is known as quarry water. Some kinds are only a step removed from soft stone, and form upon their surface a crest or covering almost impossible to penetrate with the chisel ; while at the depth of half an inch the stone may be scratched with the thumb nail. This crust is the result of the evaporation of the quarry water. This water coming to the surface of the stone brings with it a certain quantity of dissolved carbonate of lime which crystallizes and forms the crust above referred to. It is twice as easy to work stone with quarry water in it as it is when the water has evaporated ; but this is only possible in certain climates and seasons.

Water freezing within the pores of a stone must exercise a disintegrating action ; and this action often completely destroys the stone for building purposes when quarried in the winter and exposed to the influence of frost.

In the Use of Stone for Building Purposes and Walls generally, it is important that the architect and builder should have a fair knowledge of rocks and the quarries from whence the stones

are obtained; hence, there is herewith given some concise definitions of oxides, and the formation of various Rocks found and in use for Building purposes generally.

Lime is oxide of calcium.
Soda is oxide of sodium.
Silica or *Quartz* is oxide of silicum.
Alumina is oxide of aluminum.

Rocks:—Feldspar is a double silicate of alumina and an alkali; there are many varieties, and it is nearly as hard as quartz.

Hornblende is a double silicate of iron and alumina: it is slaty in structure, but generally a mass of prismatic crystals, sometimes fibrous, but not elastic. Among the varieties is *asbestos; which is pulverized and used as fire-proof paint, and woven into felt for roofing, etc.*

Syenite is hornblendic granite; it has the same feldspar and quartz as granite, but has hornblende instead of mica; it resembles the mica granites very closely, but does not split well.

Granite consists of feldspar, quartz and mica: it is the most granular of all rocks. The quartz is usually white and glassy. Feldspar is light red or yellowish white, and the mica is in little packages or sheets of any color to black. Immense quarries of all shades of granite are found throughout Maryland, also in Virginia, New Hampshire, Massachusetts, and in most of the United States. The Equitable Building, Broadway, New York, is built of Concord Granite; it is an excellent stone building. The Staats Zeitung Building opposite the City Hall, N. Y., is built of two kinds of Granite; the first story is Quincy Granite; the other stories are of Concord. The Western Union Building, N. Y., is built of a light grey granite from the vicinity of Richmond, Va. (the bricks on the fronts are from Baltimore).

Gneiss is a form of stratified granite, obscure and irregular in strata; it is somewhat crystaline; it is a metamorphic rock, not valuable generally for building purposes.

Schists are rocks composed of finer materials than the gneiss. Schists are stratified; the strata generally lays flat. This is also a metamorphic rock.

Slates are the finer grained schists. The clay slate is the finest grained of the slate; the talcose slate is the most metalliferous, the mica next, and the clay slate next.

Marble is the purest form of carbonate of lime (except stalactites), and is an earlier formation of limestone, with a pressure which retained the carbonic acid. The Marble residence erected for A. T. Stewart, in New York, is built of selected White Marble from the Westchester County quarries of N. Y. The Mutual Life Insurance Company Building, of Boston, Mass., is built of Marble from the quarries of Westchester County, N. Y. The Drexel Building is built of Connecticut Marble.

Calcite, or *Carbonate of Lime* consists of transparent crystals when pure, but changes color with impurities, becoming white marble, or blue, yellow or grey limestones.

Gypsum or *Sulphate of Lime, i. e.*, the result of the action of the oxide of sulphur on oxide of calcium, is known as Plaster of Paris.

Oxide of Iron is a rock-building mineral, and is diffused through nearly all rocks; makes great rock masses by itself; oxide of iron in limestone or sandstone injures it for dressed stone surfaces.

Talc is a silicate of magnesia with some potash and iron, greasy of touch; allied species are soapstone and serpentine.

Serpentine is a greenish melted rock; it is almost entirely made of talc. Some varieties are used for fine masonry.

Green Stone is composed of feldspar and hornblende; it is granular and very tough and hard; it is the metamorphic form of the igneous rock, diorite.

Diorite is hornblende and feldspar; is grayish white sometimes with speckles of dark green spots.

Basalt consists of feldspar, augite and chrysolite, and often with iron in small proportions; it is dark grey or green to black. A basalt stone of dark color is extensively quarried in New Jersey for rough walls and foundations.

Dolerite is basalt with chrysolite left out, and is not so often green like basalt.

White Trap is a pure feldspar; white trap is used extensively in New York for paving stones.

Sandstone. A Rock composed of sand agglutinated. Compact sandstones are used, for fronts of buildings; for instance, Bellville, N. J., brown stone, or Connecticut brown stone, etc.; Friable Sandstone is not suitable for constructive purposes;

Ferruginous sandstone; this becomes discolored in spots; Concretionary sandstone; Micaceous sandstone, is sandstone with scales of mica: Argillaceous sandstone contains much clay with sand; also called Shaly stone when thin and laminated. Marley sandstone contains carbonate of lime, so as to effervesce when treated with weak acid.

Veins are the crevices and fissures of the rocks, filled with other substances than the rocks.

Hydraulic Lime is any combination of lime with very silicious clay.

Marl is simply limestone; has been so recently formed that it has not yet become compacted into solid rock.

Pozzoulana Tufa is an earthy rock, not very hard, made from volcanic cinder, more or less decomposed, usually of a yellowish brown color; it is used for hydraulic cement.

Sand is comminutive or pulverized rock of any kind; but common sand is mainly quartz, or quartz and feldspar.

Pink and Red Granites—The color occurs in feldspar. When used in buildings they produce a fine effect, and can be highly polished. Also, when it is the intention to use a stone without cutting the surfaces, and only squared with a tooled face, and where the edges are axed, it is very fine in effect. Dark-red granite, equal to the Scotch, is now quarried in Nova Scotia.

The foregoing list* gives the average kind of rocks and sandstones of the earth used in construction, etc. There are many varieties, not necessary to name here, with names peculiar to the location of quarries, and varieties with traces of metal, etc.

Strength of Building Stone.—The strength of the building stone used in some parts of this country have been investigated by crushing tests at the Columbia School of Mines, at the Navy Yard in Washington, and in other places.

The result of these tests show, that the strongest of our building stones are the trap rocks of New Jersey and Staten Island, which bear a pressure of 24,000 lbs., per cubic inch. They are not used, however, owing to the cost of working them, except where the blocks may be fitted together roughly.

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* We are indebted to the book of Mr. F. H. Smith, for the definition of some of these terms.

The strongest granites come from Westerly, R. I., Richmond, Va., and Port Deposit, Md. The largest variety of granites come from this State and are of all shades of grey, green and salmon colors. These will stand a pressure of 17,750, 21,250 and 19,750 pounds respectively to the cubic inch. Granite is the most durable of all stone in every day use. The fine red polished granites, so much used of late, come from Peterhead, near Aberdeen, Scotland, and the bay of Fundy, and to all intents and purposes will last forever.

The strongest marbles come from Lee, Mass., and bear 13,440 pounds to the cubic inch, and Tuckahoe, N. Y. 12,650 pounds. These are stronger than the bay of Fundy granite, which stands a pressure of only 11,812 pounds to the cubic inch. Italian marble will bear 11,250 pounds, and the statuary marble Carrara only 9,723 pounds pressure to the cubic inch.

Good rough marbles are found in Westchester County. The strongest limestone comes from Kingston, N. Y. It will resist 13,900 pounds to the cubic inch, and has the greatest variety of colors of all building stone.

That from Glens Falls takes a high polish and is jet black, that from Lockport is gray, and the delicate cream and dove tints are found in the Athens and Caen stones. Lighter shades are found in the Bermuda and Florida rocks.

The gray Lockport stone when dressed by the hammer resembles a light granite, and is frequently used for trimming brick houses. The cream-colored limestone of Paris basin is very soft at first, and would be esteemed by a green hand unfit for any purpose, but it hardens when dressed, and can be used for the most delicate work: the exposure that would chip the work in other stones improving it. The Topeka stone from Kansas possesses the same valuable property. When fresh from the quarry it can be sawed like wood in any shape. The lime-stones that are most valued, however, in this country, come from Dayton, Ohio; they are greatly used by Cincinnati builders. In Chicago the favorite limestone is the Athens, before mentioned from northern Illinois. The lighter stone comes from the Ohio, and belongs to the lower carboniferous. A medium between the two, in color, comes from Amherst. Both are excellent for resisting

fire. Many of the finest buildings in Cincinnati are built of the Waverly sandstone of a light dove color.

Another rich stone is the St. Genevieve from Missouri, it is straw colored and finely grained. All these stones will stand a greater pressure than is ever demanded of them, 50,000 pounds to the sq. ft., being, perhaps the maximum. The pillars of All Saints Church at Angiers sustain a pressure of 86,000 pounds to the square foot, and the columns of the Pantheon 60,000 lbs. Building stones in stores, warehouses and office buildings are often used where they carry an actual load of from 60,000 to 75,000 lbs., per sq. foot. Where the load is excessive it is always best to enlarge the piers, or add brickwork to distribute the load.

Footing Stones.—

Flags or slabs of stone that are thin make poor footings, where, in proportion to the weight of the superstructure, they are car-

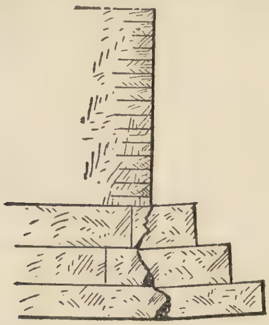


Illustration 16.

ried out to get a greater bearing. When this is done, the stone will often rend, and become displaced, through the whole batter, as may be seen in Illustration 16.

In building large masses of work, such as the abutments of bridges and the like, the proportionate increase of bearing surface obtained by the projections of the footings is very slight, and there is a great risk of the latter being broken off by the settlement of the body of the work. It is therefore usual in these cases to give very little projections to the footing courses, and to bring up the work with a battering face, or with a succession of very slight set offs. See Illustration 17.

Footings of undressed rubble built in common mortar are not

ILLUSTRATION 17.

safe ; for in case of the compression of the mortar, it is sure to displace the superstructure.

A safe way of using rubble is to break it up tolerably small, and lay it in the trenches without mortar, as it forms a hard unyielding bottom so long as it is prevented from spreading laterally by the pressure of the ground.

Where the building is of small rubble, the best way to proceed is to lay the foundations with cement mortar, so that the whole will form a solid mass. In this case the size and shape of the stone is not important.

In building with brick, the great point to be attended to in the footing courses is to keep the back joints as far as possible from the face of the work ; and in ordinary cases the best plan is to lay the footings in single courses—the outside of the work being laid, all headers and no course projecting more than one-quarter of the length of the brick above it, except in eight or nine inch walls. Where more bond is required in the work, the courses must be doubled, the heading course above and the stretching course below. See Illustration 18.

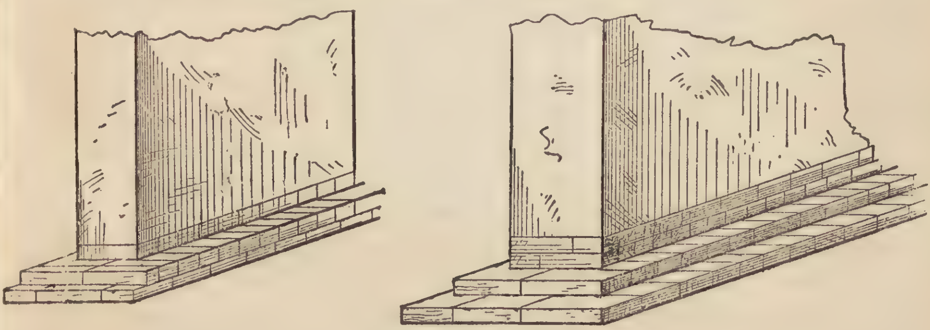


ILLUSTRATION 18.

Bricks used in trenches and for footings should be the hardest and firmest. It is desirable that the bottom course should in all cases be a double one.

Proper care and judgment should be exercised upon laying the footing courses of any building, as upon them depends much of the stability of the work.

If any rents or interstices are left in the beds of the masonry or if the materials themselves are unsound or badly put together, such carelessness will show sooner or later, and then there is no remedy ; or if one, it will be attended with great expense.

Inverted Arches used in the footings and foundation walls of superstructures, should have properly considered abutments for them on both sides. If used at the extreme angles of a building (see illustration 19), the effect of any settlement will move the corner pier from a plumb or vertical position to the dotted line shown on figure. The execution of these inverted arches should be very perfect, as any settlement in them has a bad effect on the piers, and consequently gives opportunity for that fracture which their presence was intended to obviate.

Inverted arches may be constructed with facility by moulding their backs in the ground to be occupied by them ; and this may be very exactly done by pressing down an inverted centering, removing it, and smoothing down the cement or concrete. The

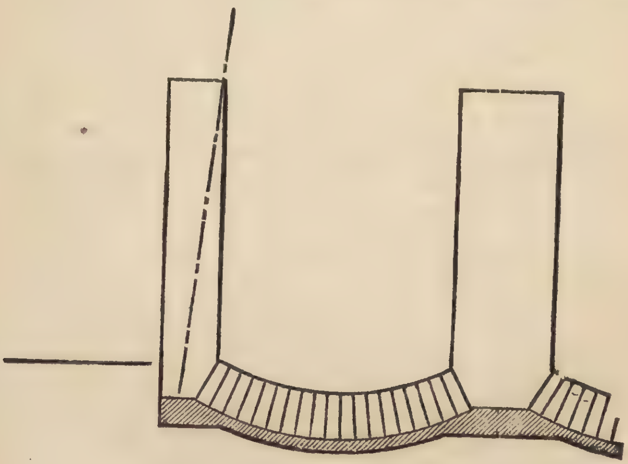


ILLUSTRATION 19.

setting of the brick or stone then becomes an easy matter. Besides foundations for buildings, inverted arches are constantly used in constructing sewers.

The parabolic form is the best for such arches ; it is the surest for resisting thrust, and besides this has the advantage of not having to be sunk in the ground so deep.

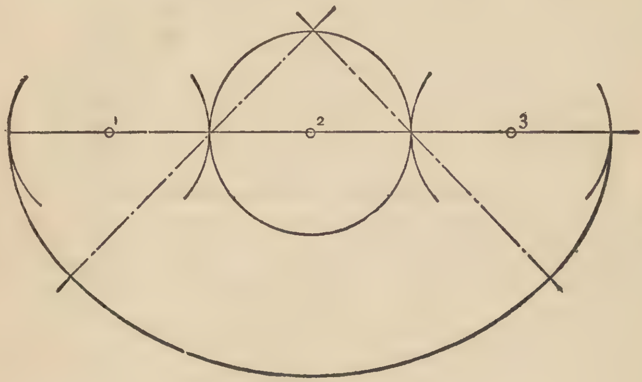


ILLUSTRATION 20.

Illustration 20 represents the method of getting the lines for centering for a curve approaching the parabolic or elliptic, and is generally used where half circles cannot be used.

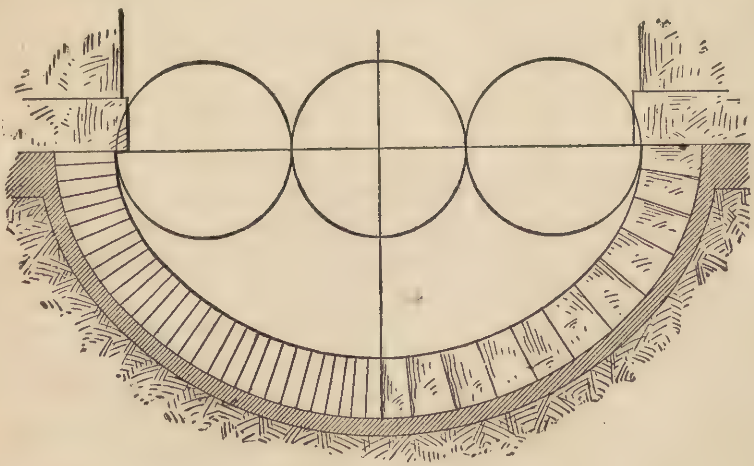


ILLUSTRATION 21.

It is sometimes required to span spaces where there is a soft bottom, when inverted arches are used. In cases of this kind a form of construction, as shown in illustration 21, may be used.

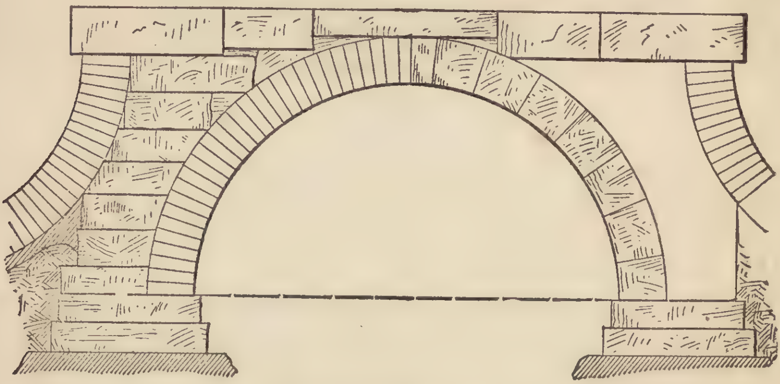


ILLUSTRATION 22.

For large spaces use the Elliptic Arch.

In cases where the ground is soft the expense of spreading out solid work to the requisite extent, renders it necessary to use some cheaper method for the footings. Three methods may be mentioned.

First. To put in a wide footing course of timber, using timber that will sustain heavy shearing strains ; it is best to char the timber.

Second. To put down a layer of concrete, using one of the various hydraulic limes in its composition. The concrete should be spread over the footings to a breadth equal to the bearing surface of the stratum below the footings.

Third. To build upon a layer of sand or gravelly deposit, with trenches dug to receive it, which pressing against the sides as well as the bottom, distribute the weight of the structure over a large resisting surface

Where it is the intention to erect buildings on soft ground, and a large bearing surface can be obtained, timber may be used with great advantage, provided the timber can be prevented from decaying. Some char the timber, and others give it a coat of asphaltum. If the ground is wet, and the timber is good, there is little to fear ; but when it is alternately wet and dry you

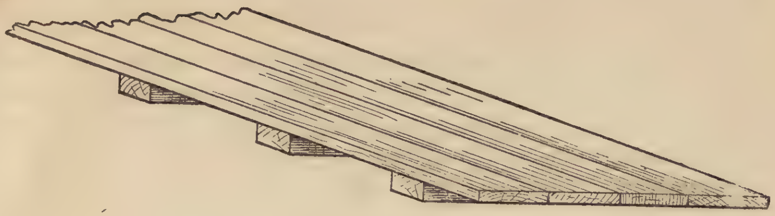


ILLUSTRATION 23.

cannot depend on unprepared timber. The kyanizing and creosoting process was used some fifteen years ago, but is seldom used now, as most localities have some method of their own, such as hereinbefore mentioned.

The best method of using planks under walls is to cut them in short lengths, which should be placed across the foundations and tied by longitudinal plank, laid to the width of the bottom course of the walls, and spiked to the bottom planking. See Illustration 23.

A common method of planking foundations is shown in Illustration 24. The space under the planking should be rammed. After this, bed the sleepers of timber in concrete, and fill the spaces between them flush with concrete to the top, so that the planking may rest on a solid level surface.

This same method is used under basement or cellar floors, to prevent rats and mice from getting in and making nests.

Before proceeding further with footings and foundations, it is important for the architect and builder to have some knowledge

ILLUSTRATION 24.

of the weight and material used in the superstructure or building to be supported on these foundation walls, and for this purpose we present the following tables :

NOTE.—Mr. Dobson, C. E., who has devoted considerable time and attention to the subject of foundations, has been consulted in some instances on this subject.

TABLE OF WEIGHT OF TIMBERS, DRY.

Green timber usually weighs one-third more than dry.

Maple	49 pounds to a cubic foot.
White Oak	51 " " " "
Southern Yellow Pine	45 " " " "
Northern Yellow Pine	35 " " " "
White Pine	30 " " " "
Spruce	25 " " " "
Hemlock	25 " " " "
Chestnut	41 " " " "
Cherry	42 " " " "
Ash	38 " " " "

WEIGHT OF BUILDING STONES, ETC., PER CUBIC FOOT.

Granite or Limestone, dressed	165 lbs. to 1 cubic foot.
Masonry of Granite, well scabbled, mortar rubble, one-fifth of mass—Mortar	154 " " "
Brickwork, mortar included,	115 " " "
Marble	168 " " "
Hardened Mortar (1 to 4 and 1 to 9)—Sand weighs	103 " " "
Serpentine Stone	162 " " "
Sand (Sand is retentive of moisture and varies greatly in weight)	90 to 120 " " "
Water	62 " " "
Clay (dry)	119 " " "
Hydraulic Rosendale Cement, American	56 " " "
Teil Hydraulic Lime	45 " " "
Common Loam Earth, slightly moist	75 " " "
Common Loam Earth, slightly moist, and firm sand, moderately packed	90 to 102 " " "
Gneiss—166 lbs. cubic foot, loose in piles	98 " " "
Hornblendic Gneiss	175 " " "

CHAPTER V.

Arches in Walls.—At the springing line of arch to walls it is well to provide stone skewbacks or corbelling, represented by Illustration 25.

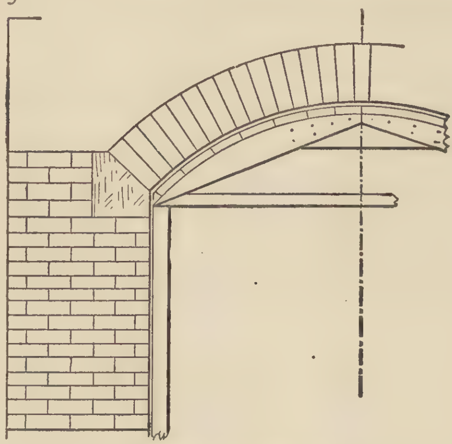


ILLUSTRATION 25.

By this method the construction of the arch does not encroach upon the piers.

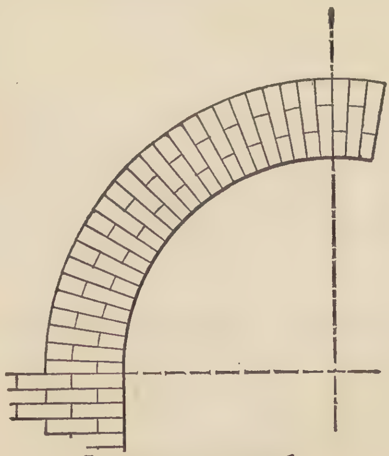


ILLUSTRATION 26.

Construction of Arches.—In constructing brick arches it is always best to specify arch brick, as they form better voussoirs than the parallel brick, and do not have to depend so much on the cement or mortar. Arches over piers or thick walls, which support a superstructure or several stories, should be constructed as shown in illustration 26, so as to bond the arch brick.

Chimney Walls and Building the same.—A broad, deep and substantial foundation is necessary below the action of frost, so that it may not settle. If the chimney becomes a part of the walls, the footings should be made proportionately broad to sustain the weight above.

The Chimney should be straight and smooth, having *no* angles or jogs if possible. No woodwork should be built into the chimney, but a space around it should be left clear.

The walls of chimneys when built six inches thick, having the bricks set on edge inside, and bonded with brick laid every four or five courses, is nearly as safe as an eight-inch thick wall. Where four-inch walls are used around flues to chimneys, it is always best to carry the smoke-pipe into a vitriolized clay pipe, this pipe to run ten to twelve feet above the smoke hole. An opening at the bottom of all flues should be provided. It is usual to have light iron frames and sheet iron doors, so that the soot may be removed at any time.

Chimneys should be smoothly plastered with mortar mixed with lime, with a small proportion of plaster of paris or cement. Some architects require all joints in flues to be pointed.

Proportion for Brick Chimneys — for manufactories using from twenty to thirty horse-power engines.

The diameter at base should be not less than one-tenth of the height.

The footings from one and one-half to twice the thickness of base of chimney wall.

Batter of chimney, three-sixteenths ; three-eighths ; or, one-half inch to one foot in height.

Thickness of brick wall at top, twelve inches.

From twenty-five to fifty feet below top of chimney, sixteen to twenty inches.

From fifty to seventy-five feet below top, twenty-four inches to two feet out four inches thick.

Such a chimney would average from six feet to six feet, eight inches square at base, with twenty inches to two feet square flue.

The batter of chimneys should reduce this size at the top to from one-quarter to one-third of the bottom diameter or side of square.

From one-sixth to one-eighth of the heighth of chimney the walls should be perpendicular, and when desired at starting line of batter, use a belt course of stone or brick.

The top of chimney should always be capped with stone or iron cap.

All brick laid on inside or outside of flue should batter evenly; they should be regular in size, sound and hard-burned, and laid with even joints.

It is sometimes necessary to remove dampness in chimney flues by building a fire in the base, with light fuel, before building the engine fires.

A chimney for any ordinary boiler should be twenty to twenty-five feet high. The location of a chimney governs the height; *i. e.*, in the vicinity of houses it should not be less than five feet above their roofs; in low-lands it is necessary to carry the top above the downward currents.

Masons' and Stone-Cutters' Tools.—The names given tools for this purpose vary according to locality, but the following names are common over the United States:

The Face Hammer. The head has one flat end, and one wedge shaped edge for roughly shaping stones from the quarry; the head is 8 inches to 10 inches long.

The Double Face Hammer weighs from twenty to thirty pounds, and is used the same as the other, but for the roughest work.

The Pick Hammer is used for rough dressing on sandstone or limestone; it is wedge shaped on both edges, with handle in the centre.

The Axe Hammer has also two wedge edges for cutting; it is ten inches long and four inches wide on each edge. It is used in reducing faces and joints to a level, and for axing a draft around the edges of stone.

The Patent Hammer is a double-headed tool, and holds a set of wide, thin chisels. The chisels are held in position with bolts on ends of head, etc. There is also a variety of tools that require only the use of one hand: The hand hammer, which weighs from two to five pounds, is used in pointing, drilling holes, and work on hard rock with chisels; the mallet is used where sandstone or limestone is to be cut; the chisels used are known as tooth chisels, splitting chisels, plug chisels for splitting rocks, etc. Stone carvers have a variety of tools, for which there are no names in particular, and which are varied according to their work.

In specifying masonry, whether patent hammered, axed, bush hammered, etc., it is best to have each estimator supply a sample cube of four to six inches of stone, all from the same stone, and of the style of work proposed to be done.

Stone-Cutting.—All stones used in buildings are as follows:
Rough stones that are used as they come from the quarry.
Stones roughly squared and dressed.
Stones accurately squared and finely dressed.

ILLUSTRATION 27.

Drafted or Axed Edge and Pointed Quarry-faced Ashlar.

Quarry-faced Stones are those whose faces are left the same as they come from the quarry, similar to illustrations.

Drafted Stones are those on which the face is surrounded with a chisel draft, the inner space left rough.

Squared Stones; all stones that are roughly squared and dressed on beds and joints, and where the thickness of joint is from one-half to one inch thick, as the case may be.

Cut Stones.—This is for all stones dressed true and square, with dressed bed and joints; the edges may be drafted and the face left rough; bush or patent hammered work on some sandstones seems to loosen the stone, and in course of time it will shell off.

Ashlar or broken ashlar masonry may have its faces cut with any of the various tools, *i. e.*, bush hammered, patent hammered, fine pointed, etc., or rubbed work; it is always known as cut work unless particularly described. (See illustration 27.)

Rubble Footings for ordinary walls are usually built as shown in figure 28, of rough stone, bedded in mortar composed of one-third well-burnt stone lime, and two-thirds clean sharp sand; *A* representing the footing.

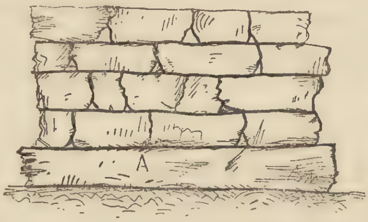


ILLUSTRATION 28.—Rubble Footings.

Bond Rubble.—Provide a sufficient quantity of stones for bonding in greater lengths than the size of the rubble stone, which are used or bedded as found in the quarry. All interstices should be filled with small stone and mortar; and at the height of eighteen to twenty-four inches the work should be routed with new made (mortar) grouting and used at once.

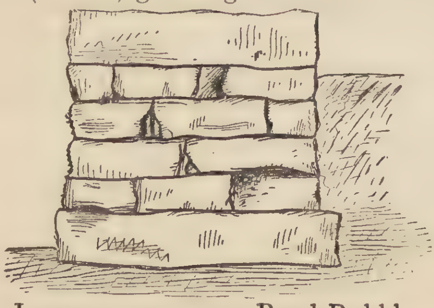


ILLUSTRATION 29.—Bond Rubble.

Random Coursed Stone Work.—Figure 30 represents neat faced and pointed random coursed work; the stones to be ham-

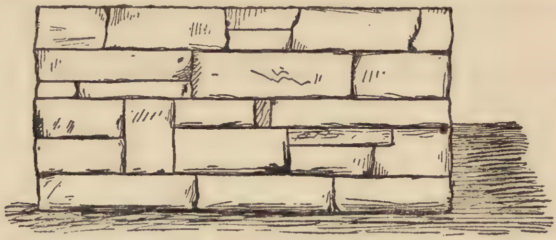


ILLUSTRATION 30.—Random Course.

mer dressed to a fair surface, or tool pointed; with neat joints well pointed with mortar.

Regular Faced and Squared Stone Work. — This is usually built above ground, for basement or exterior walls, and in areas, and is finished in neat and regular coursed work, no course more than sixteen inches or less than eight inches, as the case may be; it is hammered and dressed to a fair surface, and the joints are close and true.

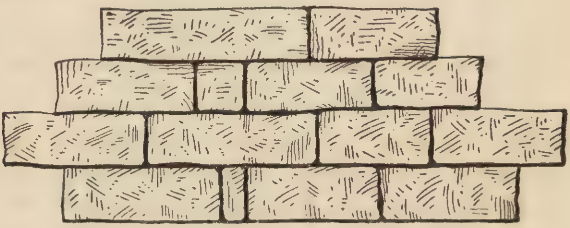


ILLUSTRATION 31.—Quarry Faced.

Trimmed and Coursed Ashlar Facing.—The faces of exterior walls of buildings are usually trimmed with ashlar facing of stone; the joints may be all square and close, or have moulded or chamfered edges with horizontal beveled joints.

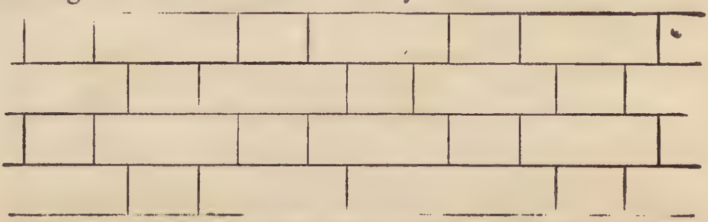


ILLUSTRATION 32.—Trimmed and Coursed ashlar facing.

The following list gives some of the stones used for the exterior of buildings for facings or ashlar work, in New York city and surroundings.

Dorchester, New Brunswick, Green Stone.—Iron sometimes appears on the surface if not selected.

Berea Stone.—Blue cast, grey ; very good ; produces fine effect in combination with brick.

Wyoming Valley Blue Stone, Penn.—Of a close texture ; used in front ashlar, trimmings, etc.; not good for flags.

Marble.—The most of the marble used in New York comes from the quarries of Westchester County. The marble for the R. C. Cathedral was quarried at Pleasantville, New York.

Canaan Marble, of Conn., is used some, and also

The White Marble of Vermont.—The fine grained marbles are quarried principally in Rutland, Pittsford and Dorset Counties.

Connecticut Free or Brown Stone is not in use now as much as formerly.

Blue Grey Stone, from Cincinnati, well spoken of.

Blue Stone Flags come from Hastings, on the North River.

Granite.—The greater part formerly came from Concord, New Hampshire, but now granites from Massachusetts, Maine, Maryland and Virginia are coming into use.

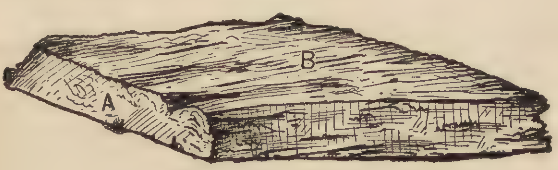


ILLUSTRATION 33.

Figure 33 represents the faces of stone before being dressed; *A*, the natural face ; *B*, bed of stone.

One of the most beautiful building stones for residences, churches, etc., is the serpentine stone found in Chester County, Penn. It is known to preserve its freshness of color, which is a pale green, varied, in some specimens, by darker shades of the same color. It is valuable as a building material, and affords a pleasing variation from the monotonous effect of rows of brick or brown stone buildings.

Openings in Heavy Walls.—It sometimes occurs in building walls that an opening is required of a certain height, where a semi-circular arch cannot be used, and yet the wall has to sustain an immense load. In a case of that kind it is best, where brick has to be used, to make the construction as shown by Illustration 34. *A* represents the opening below segment arch; *B* the tier of beams to be supported; and *C* the semi-circular arch above (filled in) to sustain the total load.

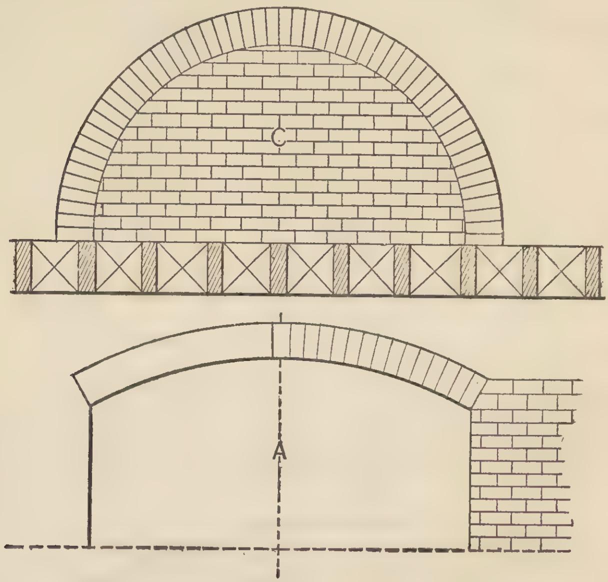


ILLUSTRATION 34.

Dry Area of Brick or Rubble.—Dry areas around buildings are sometimes made in the following manner, and covered with flat stone, or arched with brick or rubble stone (see illus. 35).

The bottom to have a descent to the drain, and paved with brick laid with hot pitch, or as the case may require.

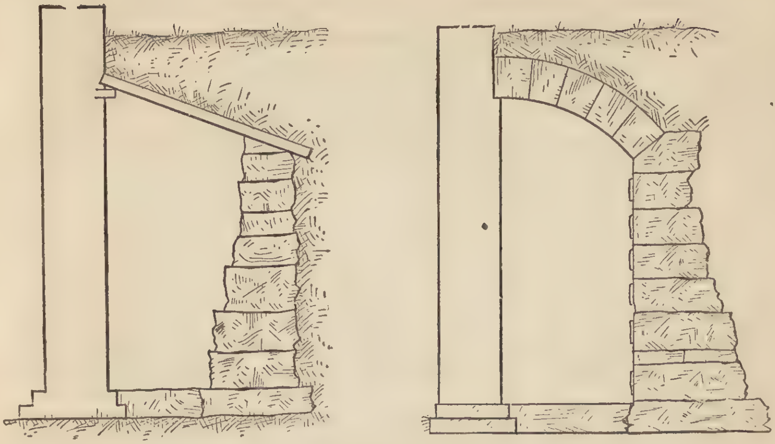


ILLUSTRATION 35.

Prevention of Dampness in Cellar Walls.—A dry cellar is one of the requisites to a healthy house. A moist or damp cellar acts as a constant reservoir of damp, chilly and impure air, and the constant movement of the air in the warmer rooms above causes currents of this air to rise and desseminate themselves through the inhabited rooms and become a constant source of danger to the health of all occupants.

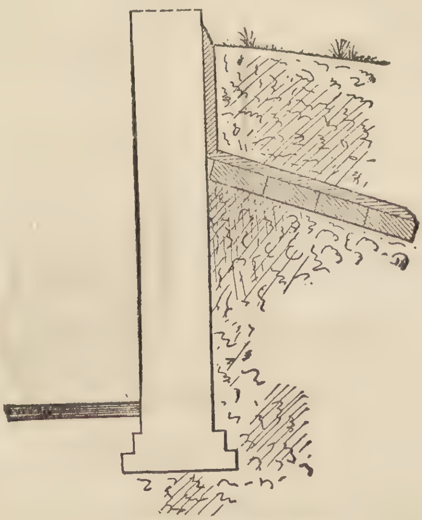


ILLUSTRATION 36.

People living over such cellars cannot but be seriously affected. Many fatal cases of sickness can be traced to this cause, and, doubtless, if our cellars were looked after more carefully, there would be less complaint of malaria and kindred ailments.

It is the purpose in this chapter to give several methods of building cellar walls and laying cellar bottoms so as to prevent the penetration of dampness.

Architects often specify that the outside of the walls be cemented from the footings to the base board of a frame house, or the base line of stone sill course of a brick or stone house. When it is not required to make a cement finish above the line of ground, then the cement is stopped off four to six inches below the ground.

In illustration 36, the earth is excavated on the exterior of walls to a width of two feet from wall, and a depth of eighteen to twenty inches, and at an angle of ten degrees descent. When this is firmly packed, lay in cement one or two courses of brick laid flat and well bedded and slushed with cement. Allow it to thoroughly dry before covering with earth.

Where this method interferes with flowers and grasses up to line of wall, that given in illustration 37 will be a more satisfac-

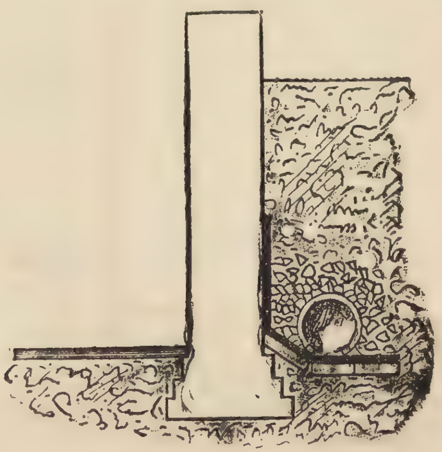


ILLUSTRATION 37.

tory method. This illustration represents a wall coated with cement on the outside or without any cement. To clearly ex-

plain the method, after the walls have been built and cemented on the outside (Rosendale cement is good for the purpose), excavate the earth on the outside to the line of bottom of footings, fill with firm earth to top of footings, pack in carefully, and grade surface to a proper descent, of not less than half an inch to the foot. It would be better to give it an inclination of two or three inches to the foot. Then on this trench or surface lay brick as shown, slushed with cement, and on the brick put a coat of cement not less than 1 1-2 inches thick, as shown by black lines, and wait for it to dry. Then set drain tiles of the form shown, they are of various forms (some having holes in the sides). On top of this put loosely broken stone, say three or four inches in size, and then cover the whole surface with earth, fill up and pack firmly. After a week or two fill up level with ground line and pave or sod. Where there is a clay bottom and much moisture this will not always prevent the penetration of dampness.

To overcome this difficulty, prepare the interior of the cellar as shown in illustration 39 and the outside of cellar walls as shown in 38, which will be found to operate quite successfully.

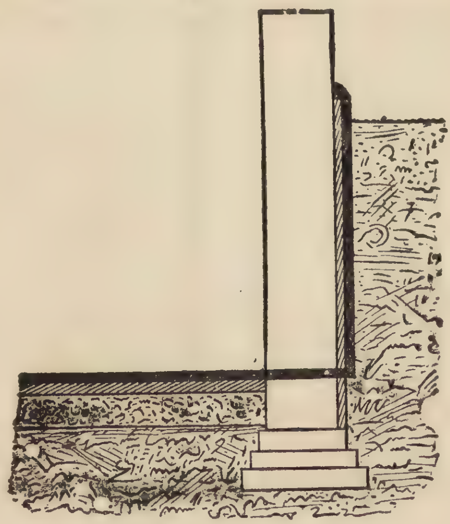


ILLUSTRATION 38.

There are clay soils sufficiently solid to support the walls of dwelling houses in which the clay in wet seasons retains moist-

ure that is not carried away into the earth, but rises and works through the cellar bottom, keeping it almost constantly damp. This is a serious difficulty to overcome, but I have known the method shown in illustration No. 38 to be carried out with success.

In this case prepare the cellar bottom and lay, say three or four inches of sand, which is to be rolled down firm and even. Following the cellar walls all around make shallow gutters in the sand. On top of this lay a coat of cement 1 1-2 to 2 inches in thickness, covering the whole surface of the cellar, taking care that sufficient descent is given to carry the water to the drain leading to sewer.

After the cement is fully dry give it a complete coat of asphalt over the whole surface and up to the inside line of brick walls, carrying the asphalt through the walls, as shown in illustration 38, up on the outside either to the earth line or above it.

Illustration 39 gives *another method of securing a dry cellar.*

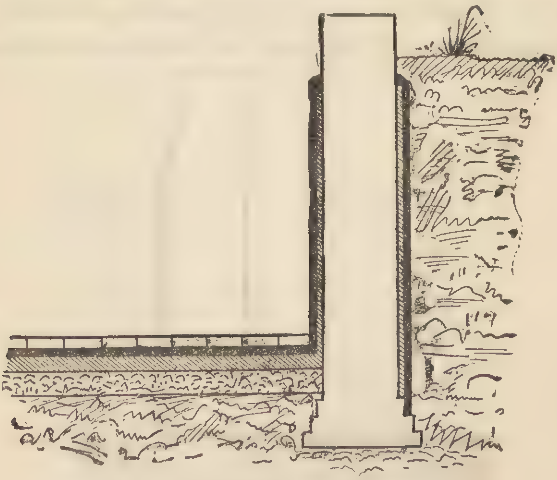


ILLUSTRATION 39.

Prepare and do all work of levelling the cellar bottom that may be required; spread over this sand to the depth of three to five inches, beat down with rammer or make it firm and hard with a heavy roller. On top of this, cover the whole surface 1 1-2 inches thick with American or English cement; carry it

well against the walls. Coat the outside walls with cement 1 inch thick in the same manner, continuing it up to ground line. When this is dry, cover the cellar bottom and inside and outside walls with asphaltum as shown. Apply while hot. Then take hard-burned, good, even brick, dip them in asphalt, and lay a floor or pavement over the entire cellar. This when properly done, makes a superior floor and a dry cellar bottom.

A good cellar floor. When the cellar bottom is not very damp and there is no moisture after rains, a bottom may be prepared thus: Cover the surface of cellar with half lime and cement mortar, and on this level, sleepers or beams for flooring; fill in the spaces between beams with concrete up to the top of beams, and on this lay the flooring.

A very durable composition for a cellar bottom may be made of cement and asphalt. Mix them in a large pan or boiler over a fire, and when thoroughly mixed and tough, spread it over the surface.

A good mixture for bedding with is 65 parts asphalt, 10 parts coal tar, and 25 parts sand. It must be used while hot.

It may be well to add that there are various ways of ascertaining the amount of dampness in cellars.

The Hygrometer Gauge is used for this purpose. The ordinary form of this instrument consists of two thermometers placed side by side, one of the bulbs being covered with muslin or similar material, and the muslin wetted with water when an observation is to be made.

When the cellar is quite dry the evaporation will be quite rapid, so that the thermometer, whose bulb is covered with the wet muslin, will mark a much lower temperature than the one with the dry bulb, but, where the cellar is damp, there will be but little evaporation, and consequently little difference in the markings of the two thermometers so that the difference in the readings of the thermometers forms a very good index of the degree of dampness.

Another instrument acting on the same principle, but more finely adjusted, is called the Psycrometer.

Sylvester's Process for Repelling Moisture from External Walls.—The proportions are first: Mix three-quarters of a pound

castile soap with one gallon water; second, mix one-half pound alum with four gallons water. These substances to be perfectly dissolved. The walls should be clean and dry, and the temperature not less than 50° Fah. when the composition is applied.

Put the soap wash on when boiling hot with a flat brush, and do not work to a froth. Let it dry twenty-four hours, or be perfectly dry. Then put on the alum wash at about 65° Fah. for the mixture, it should dry perfectly before putting on the soap wash; this is to be repeated alternately until the wall is impervious to water. The alum and soap forms an insoluble compound.

Damp.—After reading an article with the heading "Damp" in a foreign journal I was induced to make the following memoranda, to suit the subject in this country: i. e.:

The causes of dampness in buildings are: The presence of water in the atmosphere and soil: and the porosity of building materials which absorb it.

Its *effects* are well known and may be classed as Disintegration of masonry with injury to any interior finish; paper or kalsomining.

Decay of timber and injury to wooden furniture.

Developement of Saltpetre on walls, and mouldy surfaces.

Injury to the health of the inhabitants.

"The decay of timber used in building often causes structures to become unsafe as the ends of all the timbers may be laid in a damp place or built in, and completely covered with cement or lime; this causes dry rot to set in very soon and the timber becomes useless.

Where chestnut or poplar beams are used, they decay so rapidly if used in damp places that after one or two years, there is only a shell left, that may give away, when subject to any load.

The prevention and cure of dampness may be accomplished by the employment and use of material suitable for cellars and other parts of buildings below or on the level of the soil. In some cases provide drains to carry away from the outside soil adjoining the cellar walls all moisture, and again cement the outside walls from the trenches to level of the earth, and if it is a clay soil and there is much moisture put a thick coat of hot as-

phaltum on the cement. If this cannot be done outside coat the walls with cement and asphaltum inside; the same may be applied to the cellar bottom.

Where dampness is absorbed and rises in the walls from below at the cellar bottom it is best to provide damp courses, of asphaltum coated brick, grooved heavy enamelled brick; sheet lead, slate, copper or glass brick and a course of asphaltum through the whole thickness of walls.

To protect the outside faces of walls from dampness, where the walls are below ground: build a four inch brick lining; set off 2 inches on the inside of the walls. If not, build the 4-inch damp course on the outside with the two-inch air space, a small space at the top must be left open to allow the moisture to evaporate. Wooden strips may be painted with bituminous paint and used to lath on, and a coat of plastering put on the whole surface. A coating of cement and asphaltum may be used on the walls for the same purpose. Sufficient protection may be gained in some cases by using drain tile on the outside, starting the tile from the wall line and carrying six to eight feet from the walls with a descent of say 4 inches to the foot.

Hollow Brick Walls and also hollow bricks are used extensively now; these have to be laid in such a manner that the headers do not abutt against any inner bricks, and the stretchers are laid similar to the flemish bond method of laying bricks—see this subject under the heading of hollow brick walls.

The most thoroughly sanitary foundation for a building is concrete: cover the whole area that is to be covered by the building, with a four-inch layer of concrete composed of two-thirds broken stone and one-third mortar; the mortar to be made of sand and lime.

Well puddled clay is said to make a good bottom for foundations and cellar floors; but this can only occur in extraordinary cases and localities.

Puddle clay and mix it in heaps with ordinary slacked lime, and burn as is done in the making of cement, after this it may be mixed with a sufficient quantity of lime and water to work it; lay this all over the whole space of building and a space of 18 inches outside of the building lines.

Gas refuse has been used to cover the interior surface of damp walls and filling all the space on surfaces of stone, brick and mortar; but the offensive odor from this method is its most objectionable feature.

Good results have been reported from the use of a solution made of soap and alum, the result of the chemical reaction which follows is to fill the pores of the brick or stone with a fatty substance which opposes passage of water.

Dampness often penetrates or water finds its way into cellars under window sills: to avoid this turn up one course of brick inside against the sill.

Floors in Damp Locations.—A German newspaper of 1882, gives a lengthy report by Herr W. Lang—on various methods used to gain a strong and durable flooring on the earth, or cellar bottom in a manufactory, that would be dry and stand the wear of loaded trucks rolled over its surface. At first a layer of cement on a concrete floor was used; but the necessity of washing the floor, together with the wheels cutting the top surface, soon completed their destruction. Two other methods were tried. "After laying a fresh bed of concrete, a layer consisting of sand and cement in equal parts about 1 1-4 inches thick was laid, it was well rammed down and then smoothed with a hand iron. *This method made a separate shell on top, the same as tried at first.* The second method consisted of mixing a concrete of one part of cement, two parts of sand, and four parts of gravel, laying it evenly and ramming it until a layer of from 3-4 of an inch to 1 1-4 inches appeared on the surface without any gravel; this layer was then levelled and smoothed down. This floor proved to be very good; in all cases the thickness of concrete depends upon the solidity of the bottom that it is put upon, if left to thoroughly harden it will resist for a very long time any ordinary pressure."

In this article is a long account of some secret method of preparing a concrete that would effectually prevent the action of acids. In cases of this kind it is best to use stone slabs, packing the joints with lead or sulphur cement, run in in such a manner as to be able to key underneath, as the action of acids on cements and asphalts very soon destroys them. One of the strongest and best road surfaces or floor surfaces that can

be put down readily is by a method used in Pine Street, New York, as follows: The space to receive the floor is excavated and cleared of all refuse and rolled to the level surface required for the whole material. On this broken stone sufficiently large for concrete (say stone that will pass through a ring 2 to 3 inches in diameter), is laid to a depth of 6, 8, or 12 inches, and the whole surface slushed with cement, and this is rolled and before it is dry, a coating of sand is laid to raise and make an even surface. When this is sufficiently dry there is put on the top a composition composed of powdered lime stone or marble dust as coarse as sand, and mixed with an equal quantity of coarse, sharp sand, this is heated in large wrought iron pans, and asphaltum is mixed in with it to make a stiff pliable cement. When this is thoroughly mixed and before using, the concrete is covered in a rough, scratched manner with hot asphalt, and then on this the composition is spread from buckets with shovel, etc.; as soon as it is in position it is rolled evenly. A sufficient quantity is made to cover an area of say 25 feet square each time, the joints are cut very smooth and true and when connected a smooth hot trowel like iron is used to weld the joints. The whole surface is then covered with sand; the smoothing iron is used on all gutters to make the descent of water perfect. The day after some of this was finished, I saw a two-horse wagon loaded with brick run on it. The horses backed, turned, and the brick was unloaded without any injury to the surface or any part of the work.

As it is important in the construction of foundations of all structures to be prepared for various emergencies, the following receipts will be useful in nearly every case.

Air and Water Tight Cement for Casks and Cisterns.—Melted glue, 8 parts, linseed oil, 4 parts; boiled into a varnish with litharge; hardens in 48 hours.

Cement for External use.—Ashes 2 parts, clay 3 parts, sand 1 part; mix with a little oil, very durable.

Cement to resist Red Heat and Boiling Water.—To 4 or 5 parts of clay, thoroughly dried and pulverized, add 2 parts of fine iron filings free from oxide, 1 part of peroxide of manganese, 1 part of common salt, and 1-2 part of borax. Mingle

thoroughly, render as fine as possible, then reduce to thick paste with necessary quantity of water, mixing well; use immediately, and apply heat, gradually increasing almost to a white heat.

Cement to Join Sections of Cast-iron Wheels, &c.—Make a paste of pure oxide of lead, lithage and concentrated glycerine. This cement is unrivalled for fastening stone to stone or iron to iron.

Soft Cement for Steam boilers, Steam pipes, etc.—Red or white lead, in oil 4 parts; iron borings 2 to 3 parts.

Gas-fitter's Cement.—Mix together resin 4 1-4 parts, wax 1 part, and Venetian red 3 parts.

Plumber's Cement.—Black resin 1 part, brick dust 2 parts; well incorporated by melting heat.

Coppersmith's Cement.—Boiled linseed oil and red lead mixed together into a putty, is often used by coppersmiths and engineers to secure joints, the leather or cloth washers are smeared with this mixture in a pasty state.

Composition to fill the Holes in Castings.—Mix, one part borax in solution with four parts dry clay. Another: Pulverized binoxide of manganese, mixed with a strong solution of silicate of soda (water-clay) to form a thick paste.

Cast-Iron Cement.—Clean borings, or turnings of cast iron, 16 parts; sal ammoniac, 2 parts; flour of sulphur, 1 part; mix them well together in a mortar, and keep them dry. When required for use, take of the mixture 1 part; clean borings 20 parts, mix thoroughly, and add a sufficient quantity of water. A little grind-stone dust added, improves the cement.

Best Cement for Aquaria.—1 part, by measure, say a gill of lithage; 1 gill of plaster of paris: 1 gill of dry white sand; 1-3 a gill of finely powdered resin. Sift and keep corked tight until required for use, when it is to be made into a putty by mixing in boiled oil (linseed) with a little patent drier added. Never use it after it has been mixed *with the oil* over 15 hours. This cement can be used for marine as well as fresh water aquaria, as it resists the action of salt water. The tank can be used immediately, but it is best to give it 3 or 4 hours to dry.

CHAPTER VI.

Front Vaults.—An important part of the construction of store buildings in our large cities is the excavation and building of vaults under the streets, or under the sidewalk and area. See abstract of Laws in reference to vaults, chapter iii.

These vaults are usually lighted by setting thick glass in iron frames over the area known as area patent lights—and the side-

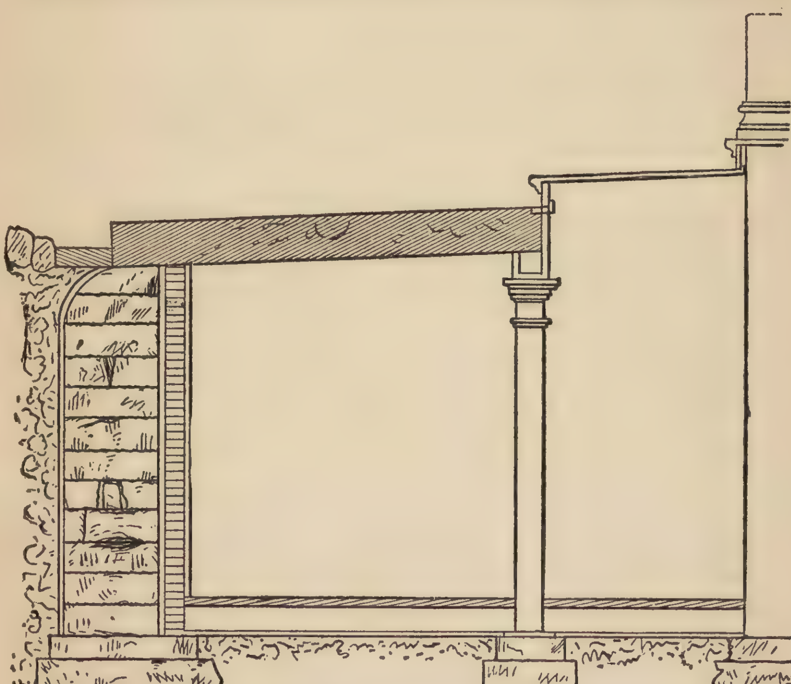


ILLUSTRATION 40.

walk is covered with arched brick-work, and on top of this stone flags, or with large flags of stone, resting on a girder or beam supported by columns where necessary. The best stone in use here is the North River blue-stone and is generally used ten

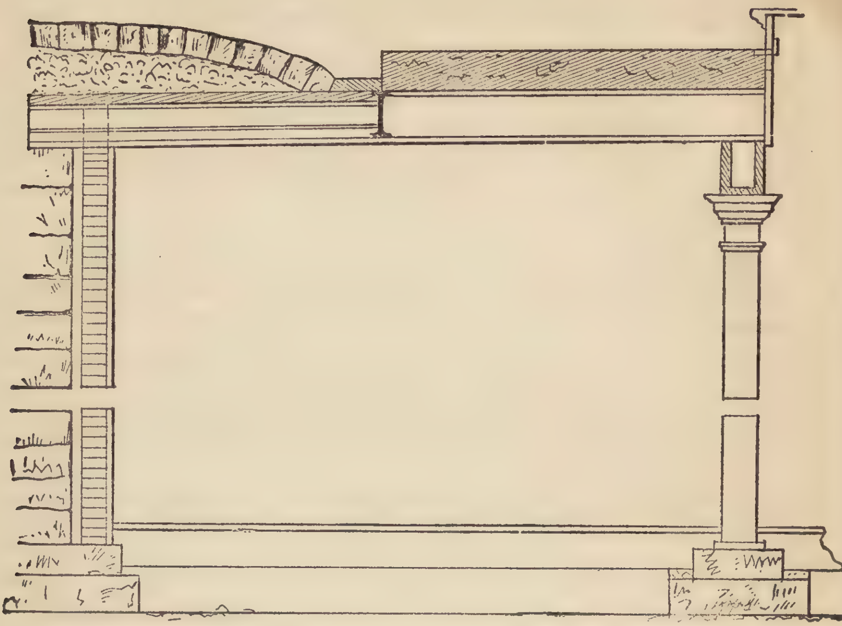


ILLUSTRATION 41.

inches thick. Where granite has been used for the purpose it has worn so smooth as to become objectionable. The joints of the stone are caulked with oakum, and filled with pitch and cement. See illustration 40.

The top of walls are usually coated with asphalt cement. The outside retaining wall is usually two feet six inches to three feet thick, with a hollow space of two or three inches, and an inside eight-inch wall.

Illustration 41 represents the construction of an area where the walls and vault are extended out under the street beyond the curb. For this arrangement there is generally required a special permit.

Vaults under sidewalks are sometimes carried to the depth of twenty-five feet below line of curb, and make two stories extending under sidewalk ; the outside retaining wall is usually of stone.

Retaining Walls.—The nature of retaining walls when used in connection with buildings can be more readily decided upon than of revertment and abutment walls used in engineering practice. One of the great obstacles to overcome in retaining walls

used for area walls around structures, is to prevent the water that penetrates through the soil and reaches the wall from freezing, and forcing the wall outward. To avoid this: when the wall is built finish the top with a flat course under the coping or capstone, and cover this with a coat of melted asphaltum, and carry this asphaltum down to the bottom of the footing courses on the outside.

The following table of slopes is given as a guide in providing retaining walls at the base, and to form a correct idea of the force of the soil or earth thrusting against the retaining wall.

Slopes.—(A slope is an inclined bank of earth on the sides of any kind of cutting or embankment.

The various Angles are according to the nature of the soil and the height of the slope.

The allowance is about as follows:—

TABLE OF SLOPES.

Gravel, sand, or common earth cuts or banks of less than 4 feet,	1 Base to (1)	Vertical.
Clay cuts or banks of less than 4 feet,	2 Base to (1)	"
Earth of mixed sand or clay or banks of 4 to 15 feet,	1 1-2 Base (1)	"
Pure gravel or sand or banks of 4 to 15 feet,	2 Base (1)	"
Clay in banks of 4 to 15 feet,	2 " (1)	"
Statified clay and sand cuttings 4 to 15 feet,	3 Base to (1)	"
Broken rocks in banks over 15 feet high,	1 1-2 " " (1)	"
Earth of mixed sand and clay or banks over 15 feet high,	2 " " (1)	"
Pure gravel or sand cuts over 15 feet high,	2 " " (1)	"
Clay cuts or banks over 15 feet high,	3 " " (1)	"
Statified clay in cuttings over 15 feet high,	3 to 4 " " (1)	"

The natural strongest, and ultimate form of a slope is a curve, and the flattest part is at the bottom. When the slopes remain without retaining walls, cultivation, sodding and drainage are preservatives.

The average angle to revertment or retaining walls is as follows:

1-4	Horizontal	to 1	perpendicular.
1-2	"	" 1	"
3-4	"	" 1	"
1	"	" 1	"
1 1-2	"	" 1	"
1 3-4	"	" 1	"
2	"	" 1	"

The average thickness of Area or Retaining walls as given in Mr. Trautwine's work.

"For walls of cut stone or first-class large range rubble laid in mortar, is 35 per cent. of height for width of base.

For walls of good common scabbled mortar rubble or brick, 40 pr. ct. of height for width of base.

For walls of well scabbled dry rubble, 50 pr. ct. of height for width of base.

When the walls are not sufficiently thick to sustain the shearing force they will bulge, and very soon the rain and frost acting on them will seriously damage them, and will cost more to repair than the original expense of walls of sufficient thickness properly bonded.

When retaining walls have been built, and where it is possible; horizontal layers of soil should be packed in behind the walls; this will relieve the force of material from pressing against the walls.

In cases of this kind and where good stones are used and laid in cement, 1-8 of the height of wall may be used for thickness at the base, and if hard burned full size bricks are laid in cement, 1-10 of the height of walls may be used for thickness at the base, to this may be added a 2-inch air space to carry off dampness, with tent holes at the top and an inner 8-inch wall secured with iron straps. Where walls of this kind are built longer than 25 feet, counterforts or buttresses bracing the retaining wall can be used. Then inside counterforts or buttresses should be built at regular intervals.

Slate is now used very extensively in our large cities for platforms and steps where stone had been formerly in use; instead of stone it is often used for Sidewalk flagging, Bond stones, Coping stones, Sills, Lintels, and floors of Lavatories, Urinal Rooms and Kitchens. As it is sawed and planed it can be laid with great regularity, and various quarries now furnish it in even colored slabs, so that when used in broad surfaces it makes a complete finish.

When tested with blue stone it is found sufficiently strong for most of building purposes, flagging particularly.

TEST.

	Length.	Breadth.	Depth.	Distance bet. bearings.	Ultim. Strength
Blue Stone,	15.90	11″.75	1.98	11 3-4 in.	8,300 lbs.
" "	15.80	11.90	3.85	11 3-4	29.050 lbs.
Slate,	15.80	11.75	1.97	11 3-4	9.150
"	15.80	11″.90	3″.80	11 3-4	17.000

in this case the load was placed in the centre.

The ultimate strength of Blue stone and Slate is (compression test) about 25,000 lbs. per sq. inch. They break into fragments with the same load.

Slabs of 6 feet by 12 feet by 3 inches thick are readily made square and true.

TABLE OF STRENGTH OF STONE FOR VAULTS, PLATFORMS, GALLERIES, BAY-WINDOWS AND OTHER PURPOSES.

Transverse Strength of Flagging.– *W*, width of stone in inches; *T*, thickness of stone in inches; *D*, distance between bearing in inches.

The Breaking Load in Tons of 2000 *lbs. for a Load on the Centre of Surface.*

$$\frac{W \times T^2}{D} \times$$

Quincy Granite	.622
Black Granite	.430
Blue Stone Flagging	.744
Belleville, New Jersey, Freestone	.312
Dorchester Free Stone	.264
Caen	.144
Ambigny	.216

Thus a blue stone flag, 100 inches wide, 6 inches thick, resting on a bearing, or on beams, 72 inches to centres, would be broken by a load resting midway between the beams or support

$$\frac{100 \times 6^2}{72} \times .744 = 37.20 \text{ tons, breaking load.}$$

TABLE OF EXPERIMENTS ON BRICK.

BRICKS.	*Fractured in lbs.*	*Crushed in lbs.*	*Fractured sq. in.*	*Crushed sq. in.*
Common Hard Brick	20,000	46,000	625	1435
" "	12,000	30,000	375	935
Dry Pressed Staten Island	20,000	50,000	625	1562
Philadelphia (whole)	15,000	60,000	468	1875
" (half)	20,000	54,000	625	3375
Massachusetts Flint	50,000	not crushed	1562	....
Colabargh	40,000	60,000	1250	1875
Firebrick	......	20,000	....	625
New Jersey, unburnt	13,000	15,000	406	468
Best Hard North River Pavers (half)	38,000	55,000	2375	3437
North River whole Brick not injured at	......	60,000	....	....

Adamantine Press Cis-brick, crushed at 90,000 lbs, being at the rate of 2,800 lbs. on the square inch.

It is best in using these tables not to exceed a working load of one-quarter to one-sixth the breaking load. Over vaults to warehouses allow a load of 600 pounds per square foot, and 500 pounds per square foot for stores.

RULES OR TABLE FOR CALCULATING THE WEIGHT OF MATERIALS IN BUILDINGS.

Calculate the weight of wall per superficial foot of surface, and deduct only one-half of window openings.

8-inch brick wall, weight per foot	77 pounds.
12 " " " " " "	115 "
16 " " " " " "	153 "
20 " " " " " "	192 "
24 " " " " " "	230 "
Brown Stone, 4 inches thick	57 "
" " 8 " "	114 "
" " 12 " "	170 "
Granite, per foot	166 "
White Marble	168 "

NEW YORK LAW IN REFERENCE TO LOAD ON FLOORS.

Hardware Store, weight on square foot floor surface	**350 to 600 lbs.**
Flour Store, " " " " "	**350 "**
Dry Goods Store, " " " " "	**310 "**
Public Assemblies, " " " " "	**180 "**
Tenement House, " " " " "	**100 "**
Roofs, " " " " "	**90 "**

After making calculations of loads in ten dry goods stores, they were found not to be loaded to exceed 180 pounds per square foot on the basement or first and second stories, and much less above.

Mensuration of Superfices.—Simple rules for calculating superficial surfaces of different shapes :

Triangle—Multiply base by perpendicular and divide by 2.

Equilateral Triangle—Square of any side by .433.

Trapezoid—Multiply the sum of the parallel sides by perpendicular distance between them ; divide by 2.

Parallelogram—Multiply base by perpendicular.

Trapezium—Multiply diagonal by one-half sum of perpendicular circle.

Circle— Multiply diameter 2 by .7854.

Circle—Multiply circumference by radius, divided by 2.

Ellipse—Multiply transverse axis by conjugate axis by .7854.

Cylinder—Multiply length by diameter by 3 1-7.

Hollow Walls for Buildings.—

There has not been so great a demand for hollow walls in building during the past eight years in cities as formerly, owing to the introduction and manufacture of various kinds of hollow, cellular and grooved ; fire-proof and furring material : most of these are made of cinders, ashes and clay, mixed with some form of Carbonate of lime or cement ; and some of which are worthless.

For walls that have been exposed on the exterior to weather and where there is a tendency for moisture to drive through, fire-proofing blocks of 2 inches in thickness are set against the inside of walls, these blocks are grooved on the side next to the walls, and leave an air space : where they are not used wooden strips are often used and the strips lathed. One reason why hollow walls are not built is, the Building Laws require as many brick to a hollow wall per foot in height as if it were solid, and as it is more expensive, there is not much gained in city buildings by using them.

Where stone walls are built to have an air space, it is usually done by leaving a space of 2 inches on the inside of wall of building, and building a 4 or 8-inch brick wall which is held in position with wedge anchors. If convenient, fireproof furring may be used. This furring of walls adds greatly to the warmth of a building. It may be useful to give the relative conducting power of different building materials, *i. e.*; as follows :

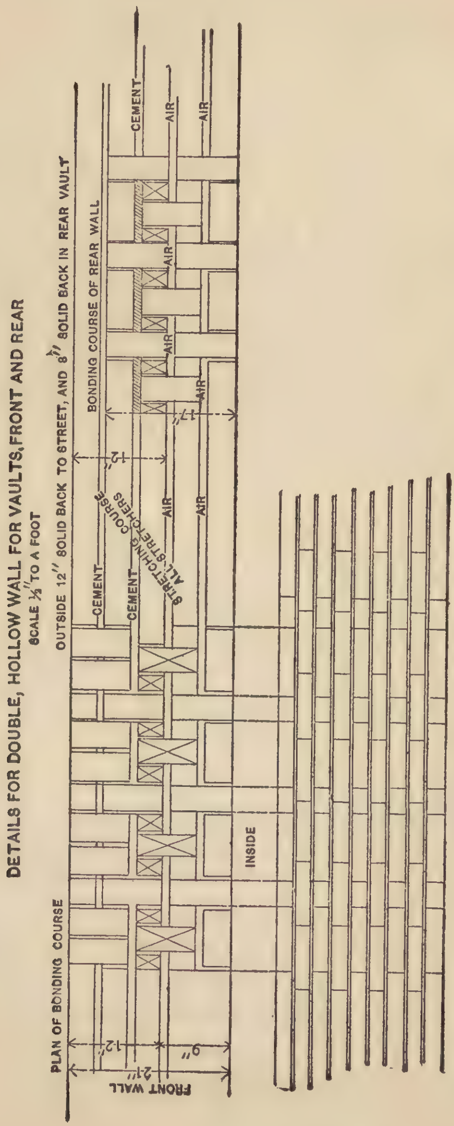
Stone 14 to 16,
Brick 5,
Plaster 4,
Wood 1,

Wood therefore is the best material named : particularly when double furring or woolen felting is used.

We herewith give illustrations 42 and 43 showing several methods of building Hollow Walls where no extra furring will be required inside to prevent the penetration of dampness.

One of the greatest protections to walls above ground where hollow walls have not been used is to give the whole surface 2 heavy coats of boiled linseed oil : there are also other methods such as silicate of soda paint and cement paints—while hollow

brick walls make a dry and damp-proof structure: the work is required to be done by skilled workmen and the joints laid clean, to leave the air spaces free.



Note. Lay up these Hollow Walls in Alternate Courses of Bonding and Stretching Courses as shown—leaving a double air-space in front of each Wall (Front and Back).

The Back or Outside of Front Vault Walls is to be built solid 12" thick, and the Rear Vault Wall to be built the same, only 8" thick.

ILLUSTRATION 42.

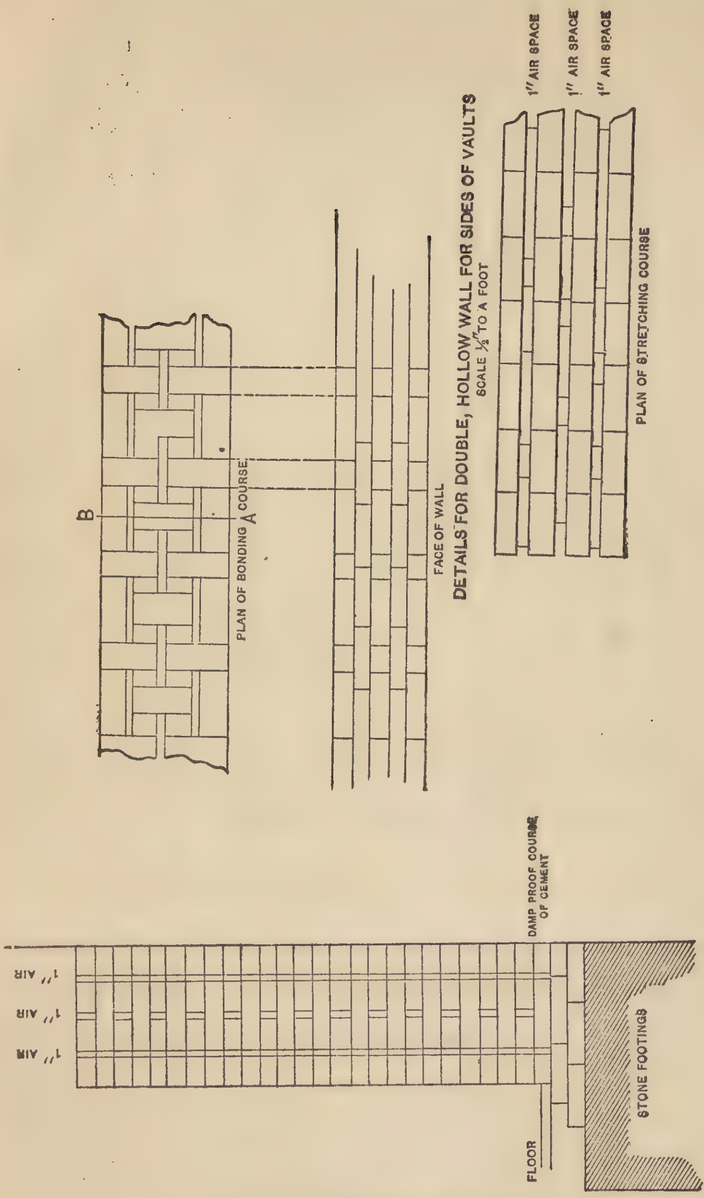


ILLUSTRATION 43.

A Stone House properly built is undoubtedly the most expensive structure that can be erected. It produces a fine, sub-

stantial and showy external appearance; and creeping vines may be grown at inner angles to produce that picturesque and home-like appearance that is seldom seen in other structures. But such a house is not any warmer in winter, or cooler in summer, than a brick one.

The proper construction for the walls of a stone dwelling, is to have the beds and joints of squared or drafted stone. This is termed squared random work. This enables the mason to more fully fill the joints with mortar.

The walls of a stone house should not be constructed of rough rubble-work, as it is impossible to fill completely all the joints with mortar; and hence in a driving storm rain will be forced through the crevices, and produce dampness; quarry-faced stone at the least should be used.

A stone house can be constructed either with hollow or solid walls, or the inside lined with hollow brick.

When hollow walls are built, the outside wall should be not less than sixteen inches thick of stone, with a three-inch space inside, and backed up with four inches of brickwork. Bonding the inside and outside walls with iron ties or clamp anchors. Where binders or headers of brick are used dampness will usually penetrate. Hollow walls to be effectual, must have outside and inside work separate from each other.

When solid walls are used they should be furred and lathed, instead of applying the plaster on the walls.

BUILDING LAWS PASSED APRIL, 1871.

Abstract from the Building Laws of the City of New York in reference to Walls, Foundations, etc., now in force.

"SEC. 3. **Depth of Foundation Walls.**—All foundation walls shall be laid not less than four feet below the surface of the earth on a good solid bottom, and in case the nature of the earth should require it, a bottom of driven piles or laid timbers, of sufficient size and thickness, shall be laid to prevent the walls from settling, the top of such pile or timber bottom to be driven or laid below the water line; and all piers, columns, posts or pillars resting on the earth, shall be set upon a bottom

in the same manner as the foundation walls. **Rock bottom.** Whenever in any case the foundation walls or walls of any building that may hereafter be erected, shall be placed on a rock bottom, the said rock shall be graded off level to receive the same. All excavations upon the front or side of any lot adjoining a street shall be properly guarded and protected by the person or persons having charge of the same, so as to prevent the same from being or becoming dangerous to life or limb. **Excavations.** Whenever there shall be any excavation, either of earth or rock, hereafter commenced upon any lot or piece of land in the city of New York, and there shall be any party or other wall wholly or partly on adjoining land, and standing upon or near the boundary line of said lot, if the person or persons, whose duty it shall be under existing laws to preserve and protect said wall from injury, shall neglect or fail so to do, after having had a notice of twenty-four hours from the Department of Buildings so to do, the Superintendent of Buildings may enter upon the premises, and employ such labor and take such steps as in his judgment may be necessary to make the same safe and secure, or to prevent the same from becoming unsafe or dangerous, at the expense of the person or persons owning said wall or building of which it may be a part, and any person or persons doing the said work, or any part thereof, under and by direction of the said Superintendent, may bring and maintain an action against the owner or owners, or any one of them, of the said wall or building of which it may be a part, for any work done or materials furnished in and about the said premises, in the same manner as if he had been employed to do the said work by the said owner or owners of the said premises.

"Sec. 4. **Base course of foundation walls, piers, columns, etc.** The footing, or base course, under all foundation walls, and under all piers, columns, posts, or pillars resting on the earth, shall be of stone or concrete; and if under a foundation wall, shall be at least twelve inches wider than the bottom width of the said wall; and if under piers, columns, posts, or pillars, shall be at least twelve inches wider on all sides than the bottom width of the said piers, columns, posts, or pillars, and not less than eighteen inches in thickness; and if built of stone, the

stones thereof shall not be less than two by three feet and at least eight inches in thickness; and all base stones shall be well bedded and laid edge to edge; and if the walls be built of **isolated piers**, then there must be inverted arches, at least twelve inches thick, turned under and between the piers, or two footing courses of large stone, at least ten inches thick in each course. **Construction of foundation walls.** All foundation walls shall be built of stone or brick, and shall be laid in cement mortar, and if constructed of stone, shall be at least eight inches thicker than the wall next above them, to a depth of sixteen feet below the curb level, and shall be increased four inches in thickness for every additional five feet in depth below the said sixteen feet; and if built of brick, shall be at least four inches thicker than the wall next above them to a depth of sixteen feet below the curb level, and shall be increased four inches in thickness for every additional five feet in depth below the said sixteen feet.

"Sec. 5. **Height, Thickness and materials of walls of dwellings.** In all dwelling-houses that may hereafter be erected, not more than fifty-five feet in height, the outside walls shall not be less than twelve inches thick; and if above fifty-five feet in height, and not more than eighty feet in height, the outside walls shall not be less than sixteen inches thick to the top of the second-story beams, provided the same is twenty feet above the curb level, and if not, then to the under side of the third-story beams; and also provided that that portion of the walls twelve inches thick shall not exceed forty feet in height above the said sixteen-inch wall. No party wall in any dwelling-house that may hereafter be erected shall be less than sixteen inches in thickness; and in every dwelling-house hereafter erected more than eighty feet in height, four inches shall be added to the thickness of the walls for every fifteen feet, or part thereof, that is added to the height of the building.

"Sec. 6. **Height, thickness and materials of walls of buildings other than dwellings.** In all buildings, other than dwelling-houses, hereafter to be erected, not more than forty-five feet in height, and not more than twenty-five feet in width, the outside walls shall not be less than twelve inches thick, and the party

walls not less than sixteen inches thick; if above forty-five feet, and not more than fifty-five feet in height, the outside and party walls shall not be less than sixteen inches thick; if above fifty-five feet, and not more than seventy feet in height, the outside and party walls shall not be less than twenty inches thick to the height of the second-story beams, and not less than sixteen inches thick from thence to the top; and if above seventy feet, and not more than eighty-five feet in height, the outside and party walls shall not be less than twenty inches thick to the height of the third-story beams, and not less than sixteen inches from thence to the top; and if above eighty-five feet in height, the outside and party walls shall be increased four inches in thickness for every ten feet or part thereof that shall be added to the height of the said wall or walls. **Buildings over 25 feet in width to have partition walls or girders and columns.** In all buildings over twenty-five feet in width, and not having either brick partition walls or girders, supported by columns running from front to rear, the walls shall be increased an additional four inches in thickness, to the same relative thickness in height as required under this section, for every additional ten feet in width of said building, or any portion thereof. It is understood that the amount of materials specified may be used either in piers or buttresses, provided the outside walls between the same shall in no case be less than twelve inches in thickness to the height of forty feet, and if over that height, then sixteen inches thick; but in no case shall a party wall between the piers or buttresses of a building be less than sixteen inches in thickness. **Corner buildings, thickness of walls.** In all buildings hereafter erected, situated on the street corner, the bearing wall thereof (that is, the wall on the street upon which the beams rest) shall be four inches thicker in all cases than is otherwise provided for by this act.

"SEC. 7. **Partition walls of buildings over 30 feet in width.** Every building hereafter erected, more than thirty feet in width, except churches, theatres, or other public buildings, shall have one or more brick, stone, or fire-proof partition walls, running from front to rear, which may be four inches less in thickness than is called for by the clauses and provisions above set forth

with regard to foundations, thickness, and height, provided they are not more than fifty feet in height; these walls shall be so located that the space between any two of the bearing walls of the building shall not be over twenty-five feet. **Iron or wooden girders, and bearing weight of same.** In case iron or wooden girders, supported upon iron or wooden columns, are substituted in place of partition walls, the building may be fifty feet in width but not more; and if there should be substituted iron or wooden girders, supported upon iron or wooden columns, in place of the partition walls, they shall be made of sufficient strength to bear safely the weight of two hundred and fifty pounds for every square foot of floor or floors that rest upon them, exclusive of the weight of material employed in their construction, and shall have a footing course and foundation wall not less than sixteen inches in thickness, with inverted arches under and between the columns, or two footing courses of large well-shaped stone, laid crosswise, edge to edge, and at least ten inches thick in each course, the lower footing course to be not less than two feet greater in area than the size of the column; and under every column, as above set forth, a cap of cut granite, at least twelve inches thick, and of a diameter twelve inches greater each way than that of the column, must be laid solid and level to receive the column. **Walls to be braced during construction.** Any building that may hereafter be erected in an isolated position, and more than one hundred feet in depth, and which shall not be provided with crosswalls, shall be securely braced, both inside and out, during the whole time of its erection, if it can be done; but in case the same cannot be so braced from the outside, then it shall be properly braced from the inside, and the braces shall be continued from the foundation upward to at least one-third the height of the building from the curb level.

"SEC. 8. **Cutting of wall.** No wall or any building now erected, or hereafter to be built or erected, shall be cut off altogether below, without permission so to do having been obtained from the Superintendent of Buildings. **Temporary supports.** Every temporary support placed under any structure, wall, girder, or beam, during the erection, finishing, alteration, or repairing of any building, or part thereof, shall be equal in strength to the permanent support required for such structure, wall, gird-

er, or beam. **Braces.** And the walls of every building shall be strongly braced from the beams of each story until the building is topped out, and the roof tier of beams shall be strongly braced to the beams of the story below until all the floors in the said building are laid.

"SEC. 9. **Headers.** All stone walls less than twenty-four inches thick, shall have at least one header extending through the walls in every three feet in height from the bottom of the wall, and in every four feet in length; and if over twenty-four inches in thickness, shall have one header for every six superficial feet on both sides of the wall, and running into the wall at least two feet; all headers shall be at least eighteen inches in width and eight inches in thickness, and shall consist of a good flat stone dressed on all sides. **Heading courses.** In every brick wall every sixth course of brick shall be a heading course, except where walls are faced with brick, in which case every fifth course shall be bonded into the backing by cutting the course of the faced brick, and putting in diagonal headers behind the same, or by splitting face brick in half, and backing the same by a continuous row of headers. **Stone ashlar.** In all walls which are faced with thin ashlar, anchored to the backing, or in which the ashlar has not either alternate headers and stretchers in each course, or alternate heading and stretching courses, the backing of brick shall not be less than twelve inches thick, and all twelve-inch backing shall be laid up in cement mortar, and shall not be built to a greater height than prescribed for twelve-inch walls. All leading courses shall be good, hard, perfect brick. **Brick backing.** The backing in all walls, of whatever material it may be composed, shall be of such thickness as to make the walls, independent of the facing, conform as to thickness with the requirements of sections five and six of this act.

"SEC. 10. **Isolated piers, how constructed.** Every isolated pier less than ten superficial feet at the base, and all piers supporting a wall built of rubble stone or brick, or under any iron beam or arch girder, or arch on which a wall rests, or lintel supporting a wall, shall at intervals of not less than thirty inches in height, have built into it a bond stone not less than four inches thick, of a diameter each way equal to the diameter of the

pier, except that in piers on the street front, above the curb the bond stone may be four inches less than the pier in diameter; and all piers shall be built of good, hard, well-burnt brick and laid in cement mortar, and all bricks used in piers shall be of the hardest quality, and be well wet when laid. **Walls and piers under girders and columns.** And the walls and piers under all compound, cast-iron, or wooden girders, iron or other columns, shall have a bond stone at least four inches in thickness, and if in a wall at least two feet in length, running through the wall, and if in a pier, the full size of the thickness thereof, every thirty inches in height from bottom, whether said pier is in the wall or not, and shall have a cap stone of cut granite at least twelve inches in thickness, by the whole size of the pier, if in a pier; and if in a wall, it shall be at least two feet in length, by the thickness of the wall, and at least twelve inches in thickness. **Base stone.** In any case where any iron or other column rests on any wall or pier built entirely of stone or brick, the said column shall be set on a base stone of cut granite, not less than eight inches in thickness by the full size of the bearing of the pier, if on a pier, and if on a wall the full thickness of the wall. **Hollow walls.** In all buildings where the walls are built hollow, the same amount of stone or brick shall be used in their construction as if they were solid, as above set forth; and no hollow walls shall be built unless the two walls forming the same shall be connected by continuous vertical ties of the same materials as the walls, and not over twenty-four inches apart. **Height of walls, how computed.** The height of all walls shall be computed from the curb level. **Swelled or refuse brick, use of, prohibited.** No swelled or refuse brick shall be allowed in any wall or pier; and all brick used in the construction, alteration, or repair of any building, or part thereof, shall be good, hard, well-burnt brick. **Bricks to be wet.** And if used during the months from April to November, inclusive, shall be well wet at the time they are laid.

"SEC. 11. **Mortar, of what materials, and how used.** The mortar used in the construction, alteration, or repair of any building shall be composed of lime or cement, mixed with sand, in the proportion of three of sand to one of lime, and two of sand to one of cement, and no lime and sand mortar shall be used

within twenty-four hours after being mixed; and all walls or parts thereof, below the curb level, shall be laid in cement mortar, to be composed of cement and mortar, in the proportion of one of cement to two of mortar. No inferior lime or cement shall be used. **Sand.** And all sand shall be clean, sharp grit, free from loam; and all joints and all walls shall be well filled with mortar.

"SEC. 12. **Walls, how carried up and anchored.**—In no case, shall the side, end, or party wall of any building be carried up more than two stories in advance of the front and rear walls. The front, rear, side, end, and party walls of any building hereafter to be erected shall be anchored to each other every six feet in their height by tie anchors, made of one and a quarter inch by three-eighths of an inch of wrought iron. The said anchor shall be built into the side or party walls not less than sixteen inches, and into the front and rear walls at least one half the thickness of the front and rear walls, so as to secure the front and rear walls to the side, end, or party walls; and all stone used for the facing of any building, except where built with alternate headers and stretchers, as hereinbefore set forth, shall be strongly anchored with iron anchors in each stone, and all such anchors shall be let into the stone at least one inch. The side, end, or party walls shall be anchored at each tier of beams, at intervals of not more than eight feet apart, with good, strong, wrought-iron anchors, one-half inch by one inch, well built into the side walls and well fastened to the side of the beams by two nails, made of wrought iron, at least one fourth of an inch in diameter; and where the beams are supported by girders, the ends of the beams resting on the girder shall be butted together end to end, and strapped by wrought-iron straps of the same size, and at the same distance apart, and, in the same beam as the wall anchors, and shall be well fastened."

Preservation of Stone.—In the preservation of stone we now lay down, from the highest practical authorities, the condition upon which only a successful issue can be obtained:

First. The materials must be irremovable and imperishable.

Second. They must be easily absorbed by, and thoroughly incorporated with the stone.

Third. The materials must be free from color, but admit of imperishable coloration.

Mr. Frederick Ransome's process seems to best fill all the above conditions, meeting most thoroughly every possible requirement. The materials used are as follows: Dissolve flint or silicate of soda and chloride of calcium. Flint or silex is soluble by heat under pressure in a solution of caustic soda. In this form it is soluble silicate of soda. In this form it is to be thoroughly brushed into the stone. On top of this is brushed into the stone a solution of chlorine, which unites with the soda, forming an insoluble silicate of lime. The silicate of lime being white, there is an opportunity of using metallic tinting solutions.

Another process for the preservation of stone or brick is to dissolve resin with turpentine, and when heated, to add linseed oil to form a paint.

Another mixture is made from unslacked lime, to which is added while slacking oil of tallow. When the slacking is complete, it is placed in a vessel with alum water and proto-sulphate of iron. After settling, it is drawn off and used.

Another process is the repeated application with a brush of a solution of beeswax in coal tar naphtha; when the color of the stone is to be preserved, white wax, dissolved in refined distilled camphene.

None of these, except the first, seem to answer any practical purpose, and only offer a temporary protection.

Here is a mixture, given by M. Kuhlman, that seems to have been used with success for thirty years. It is the silicate of potash. Before application the surface requires to be washed with a diluted solution of caustic potash with a hard brush. Three applications of the silicate are required during three days.

There is an English preparation extensively used for the purpose of repelling moisture, and for the preservation of stone, brick, plaster and cement. It is a liquid or solution of silica. It is also used in kitchens, cellars and basements to form a hard surface on the walls, impenetrable to water. It is a kind of enamel, and is put up in barrels and by the gallon, and is red, white, blue, green and chocolate. It is applied with a brush, and is very inexpensive. It presents a surface like glazed tile, and is not affected by water or atmospheric changes. It is a

silicate enameling paint. There are several agencies in the United States.

Incrustations on Brick Walls.—A greyish white substance often appears on the surface of bricks, before and after being laid in walls; it proceeds from several causes: and since the discoloration is very unsightly, and if removed, may return, many builders and owners of buildings have tried various ways to get rid of this precipitate. It occurs generally on Philadelphia and New Jersey bricks for front facings. It is not seen often on the Baltimore or North River bricks. Limes that are burned of magnesian limestone produce a lime with a mixture of magnesia, and when made into mortar, and used in brickwork, absorb sufficient vapor from the atmosphere to form a sulphate of magnesium or epsom salts. It finds its way through every crevice and pore out to the surface. This sulphate of magnesia is found in a crude form known as silicate of magnesia, in native forms as asbestos, soapstone, talc and French chalk. When common salt is used in solution on brick, it leaves a white precipitate when dry. Portland cement contains but a small proportion of magnesia, and walls built with it show but little, if any, defacement. Some of the grades of Rosendale cement that contain magnesia and soda disfigure the surface of the walls when used in cement mortar. The best remedy is to remove the incrustation and wash the fronts, and when dry, paint the surface. If the surface is painted over the incrustations, it shows different shades of color when the paint is dry. This discoloration of brick walls is most noticeable in dry weather on parts of walls subject to dampness, and on entire walls after heavy rains. North and East walls are usually the heaviest coated. This white precipitate comes from both bricks and mortars.

To avoid this white defacement, builders should use limes free from magnesia, and cements free from magnesia and soda.

Avoid using bricks that are burned with coal, and also when the dry surface of the brick is whiter than the true color. When clays are to be used for making pressed brick for fronts or ornamental purposes, it is best to avoid all clays containing epsom salts or sulphate of magnesia.

The following may be a guide to finding the magnesia in clays:

Take some clay; dry the clay by heat; reduce it to a fine powder, and saturate with sulphuric acid. Then dry and calcine the mass at a red heat, in order to convert any sulphate of iron (copperas) that may be present to a red oxide; it is then dissolved in water and sulphuret of lime is added, to separate any remaining portion of iron; then pour off the liquid and evaporate it, and the crystals that form, if any, are the sulphate of magnesia. This should be done by a chemist.

Sulphuret of Lime is made of—one part flower sulphur, two parts lime, ten parts water. This is the mixture used in testing the clay.

Of course, if the sulphate of magnesia is found, the clay is not fit for front or ornamental brick.

Yet it is possible to wash some clays and carry off the magnesia.

Another method of analyzing clay is as follows:

Grind the clay to a powder, and add diluted muriatic acid until it ceases to effervesce; heat it until the liquid evaporates, the residue being a thin paste; then add water and shake it; then filter the mixture and dry what is on the filtering paper by heating—this gives the insoluble matter; if magnesia is contained add clean water so long as any precipitate is formed; quickly gather the precipitate, and wash with pure water. The residue from washing is the magnesia.

Sand.—Whatever variety of sand is used in making mortars or cements, it should be granular, hard and gritty, sharp and angular, with a polished surface, and nearly uniform in size.

Sand, when perfectly fit to be used in mortar, will bear the test of being rubbed between the hands without soiling them.

Sand is not increased in volume by moisture, nor contracted by heat.

The finest sand screened should pass through a wire mesh one-thirty-second of an inch square: the medium size, one-sixteenth of an inch mesh.

The quality of mortar or cement depends chiefly upon the quality of the sand. The common practice of using unclean sands, or road drifts, argillaceous loams, and even alluvium or common soil cannot be too speedily abolished. Masons are apt

to compound the mortar with the soil used from the foundations regardless of quality, suitability or the natural consequences of its employment.

Clean, sharp bank sand, free from loam and screened, is generally used in mortars for buildings.

As calcium or lime is used more extensively for mortars than anything else, it may be very desirable to give the various compounds.

Calcium Oxide,	Quick Lime,
Hydrated Calcium Oxide,	Slacked Lime,
Carbonate Lime,	Limestone,
Crystallized Lime,	Marble,
Fossil Lime,	Chalk,
Sulphate Lime,	Gypsum or Plaster of Paris,
Mineral Phosphate Lime,	Apatite.

CHAPTER VII.

On the preparation of Common Mortar.

The lime, when perfectly burnt in the kiln, should be packed in casks or air-tight vessels, and kept free from all moisture, and should be opened only as required.

Unslacked dry lime fresh from the kiln is termed *caustic* or *quick-lime.* After water is added to it, it is called slacked lime. The exact quantity of water for slacking is in proportion to the quality of lime; the fat or rich will absorb more than the poor or lean. No definite rule can be given for all localities for the use of water. The average is twice the weight of water to the lime, but this is only an approximation. It is important that the mortar should be used fresh.

The best or richest limes are made from pure carbonates of lime, which usually increase to twice their volume when slacked but do not harden well in damp places. Poor limes do not expand much in volume; neither do poor limes harden well in damp places.

Limes that have been ground are usually of inferior quality, often mixed with refuse lumps and air-slacked lime.

Mortar, stuccoes or cements prepared from ill-burnt lime continue soft and dusty for a long time after being made whereas well-burnt and slacked limes soon become thoroughly indurated.

Rich limes hiss, bubble and throw off great heat during the process of slacking.

The purest limes require the largest proportion of sand and water, and harden in less time than the common limes.

Various substances are sometimes added to mortar to increase the tenacity, and they impart thereto the principles of hydraulic cement to a greater or less degree.

They chiefly consist of burnt clay, ashes, scoriæ, iron scales

and filings, broken pottery, bricks, tiles, etc. They are useful in mixing with lime or mortar to increase their hardness, but they must be pure and reduced to a fine powder.

Some of the mason builders in New York and vicinity who are large contractors, make building mortar for brick walls of the following proportions:

One barrel of lime,

Six barrels of sand—sharp bank sand,

which is calculated to lay one thousand bricks.

The average number of bricks laid in buildings around New York, Brooklyn, etc., for each man is one thousand per day. For mortars for this purpose many kinds of limes are used—Thomaston, of Maine; Briggs, North River; Snowflake lime, of Pleasantville, N. Y., etc., etc.

The proportion of one measure of quick-lime, either in lumps or ground (when lumps exceed three inches each way they require to be broken), and five measures of sand, is about the average used for common mortar by many masons. However, architects generally specify one part of lime to three of sand.

Mortar generally increases in volume one-eighth more than the bulk of loose sand.

In walls that are exposed to dampness, no lime should be used, as it will never harden properly. Cement should be used, or use burnt clay or fine brick-dust, and mix it with the lime, as this forms a kind of hydraulic cement.

Shell lime is about the same as that from the purest lime-stone.

The average weight of common hardened mortar is from 105 to 115 pounds per cubic foot.

Common grout is merely common mortar made so thin as to flow like cream. It is used to fill the interstices left in the mortar joints of masonry or brickwork, and is perhaps best when a little cement is added.

Mortar should be applied wetter in hot than cold weather, especially in brick-work, otherwise the water is too much absorbed by the brick. To prevent this, dip each brick for an instant in water in some kind of vessel, especially if dusty, as the latter impairs the adhesion.

Where there is a heavy working strain brought on piers, or parts of walls, it would be best to use some proportion of cement,

as the tenacity or cohesion in some mortars is not to be relied upon until four to six months after being used. This is only important where structures are heavily loaded or of considerable height.

The tenacity of good mortar is usually fifteen and one-half pounds per square inch, or one ton per square foot.

The crushing load may be taken at fifty tons per square foot.

Laying bricks or building walls when the mortar freezes always produces weak walls, and brings expense afterwards.

Common mortar of ashes is prepared by mixing two parts of fresh slacked lime with three parts of wood ashes and when cold to be well beaten, in which state it is usually kept for some time ; and will resist alternate moisture and dryness. By some it is considered equal to some of the water cements.

A kind of cement plaster used around exterior foundation walls is made of one part Portland cement, three parts lime, and two parts sand, with water sufficient to make a mortar. But with Rosendale cement a small proportion of lime, if any, and one part sand to one of cement is the best ; and even with this where it is exposed to dampness, it is best to coat the cement with a coat of asphaltum.

To Color Mortars.*—This may be done by the use of various colored sands. There are yellow, silver and gray sands to be had in many localities. Colored mica, put on the surface of stucco work with a thin mixture of lime-water and lime, first wetting the surface, leaves a durable and sparkling finish. Pulverized bricks, yellow or red, may be used. Pulverized dust from colored marble, also basalt dust, are all durable. Ochres stand exposure to the weather, as well as any of the pigments.

Where black has been used for pointing the joints of brickwork, the mortar requires so much black to make the color that the mortar becomes poor and washes off.

Spanish brown is a species of earth of a reddish-brown color, which depends upon the sesqui-oxide of iron.

The best quality of lamp-black made into putty and used for pointing will retain its color.

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* **There are now pigments manufactured expressly for use in mortars that are said to hold their colors excellently.**

A dry powder, known as Spanish brown, added to cement or mortar is considered a permanent color.

Gravel Sidewalks are usually laid by mixing the gravel with the sand and lime; *i. e.*, Ten bushels of gravel. One to two bushels of sand. Half bushel of lime. Of course it is required to dig trenches, and lay down common concrete or broken stone, to bed the walks on.

To Color Bricks Black.—Heat asphaltum to a fluid state, and moderately heat the surface bricks and dip them in it.

Another method is to make a hot mixture of linseed oil and asphalt; heat the bricks and dip them. Tar and asphalt are also used for the same purpose. It is important that the bricks be sufficiently hot and held in the mixture long enough to absorb the color, to the depth of one-sixteenth of an inch.

Also, **for Staining Bricks Red or Black.**—A process similar to staining bricks red will answer for staining them black, by substituting lampblack for the red employed. For the red, melt one ounce of glue in one gallon of water. Add a piece of alum the size of an egg, then one-half pound Venetian red, and one pound Spanish brown. Try the color on the bricks before using, and change light or dark with the red or brown. For staining black use the same, and instead of the alum use bi-chromate of potash. Use as soon as made, and in dry weather.

Venetian Cement.—Used for covering floors, terraces and roofs of houses, it is composed of plaster of paris, sulphur, rosin, pitch and spirits of turpentine or wax, and applied when hot.

Coal Ash Mortar.—Lime, two and a half measures; sand, two and a half; coal ashes, two and a half; and puzzolana, one and a half.

Puzzolana Mortar—For lining cisterns, consists of slacked lime, sixteen parts or measures; puzzolana, eight; sand, five and a quarter; beaten glass, four; and smith's cinders, four. This was, with the other three, used at Gibraltar in 1790.

Dutch Terras Mortar.—(Terras is a basaltic mineral found in the low counties of Holland.) This is formed of equal parts of lime and terras by measure.

Very fat lime is incapable of hardening in water.

Lime, a little hydraulic		Slakes like lime when properly calcined, and hardens under water.
" quite "		
" " "	30 per cent. clay	

Lime	*Clay*		
60 per cent.	40 per cent.	Plastic or hydraulic cement	Does not slake under any circumstances, and hardens under water with rapidity.
50 "	50 "	" " "	
40 "	60 "	" " "	
30 "	70 "	Calcareous brick puzzolana	Does not slake or harden under water, unless mixed with fat or hydraulic lime.
20 "	80 "	" " "	
10 "	90 "	" " "	

TABLE.

One Bushel Mortar	130 pounds.
One " Sand	110 to 120 "
One " Lime	80 "
One " Hair	8 "

Cattle hair is collected from tanneries. It is best of medium length, fresh and clean. Vegetable fibre of hair has been used some, but not extensively.

Plastering or Stucco.—When buildings are plastered on the exterior, or parts exposed to the weather, it is usually called stucco-work (the same word stucco is in use for inside work). But this kind of finishing rough walls is not much in use in this country.

There are two kinds of stucco ; those made of lime, and those of cement. Cement stucco is disagreeable in color, and only used where protection to the walls or a very hard surface is wanted. The cement color may be covered with paint, and when used it is often painted. In working the first coat it may be well to work it with cement plaster, and for the second coat use equal parts of quick-lime and cement with silver or light grey colored sand. Colors mixed with the stucco, such as umbers or ochres get dingy and very unsightly in time. Mineral color that is not liable to atmospheric change is the best.

To make a light brown shade, use silver or as white sand as possible, and in this mix pulverized brown stone or brown sandstone. The pulverized stone dust from colored marble may be used, also basalt dust.

Pulverized bricks, yellow or red, may be used where the color is known to be permanent. The same process as mentioned above is the best for exterior pointing, as most coloring substances wash off.

An external stucco, when made with hydraulic lime of Tiel, is composed thus: Lime of Tiel, one part; two of chalk, and two of sand.

Exterior walls have to be prepared for plastering by wetting them, and leaving the joints open and rough, and during the work care should be taken to have the green material protected from the weather, particularly drying winds or heat of the sun. This is done by using muslin or canvass on the scaffolding.

Exterior plastering or stucco is usually done in two coat-work. Both coats done about the same time—that is, the first coat is done sufficiently long for it to have set in the joints, and to sustain the second coat.

The plasterer examines his work to find any places where it has not adhered—say three or four days after the work is first done.

Lime and cement, equal parts, (thoroughly mix the lime before compounding with the cement, sand and water), mixed with sand and water makes a good stucco.

An artificial stone stucco which seems very good, is made of one part lime or cement and four parts sand, to which after slacking add four ounces potash or soda, dissolved in one gallon boiling water, and add one pound shellac. When this is dissolved mix with the plaster, and use at once.

There are quite a number of cements that do not stand well for stucco-work.

Inside Plastering—Is done in a variety of ways, from one to three coats of mortar plastering on walls, ceilings, etc.

When one-coat work is required, the plasterers have to be careful in laying or nailing the laths regular. One-coat work is known as the scratch coat, and generally finished with light hand-floating to give an even finish, to receive a white or color wash finish if desired. If it is the intention to kalsomine on one-coat work, a very good finish may be made by using some *hard-finish* on the hawk (a flat board to hold plaster on, held in

the hand), and hand-float the surface with water in the brush. Back buildings and the second stories and attics of farm-houses are often finished this way. It is very important in putting on the first coat, to press the mortar firmly between the laths so as to fill up the spaces between, and clinch over the edge of the laths. When the first coat is ready to receive the second or browning coat, the surface, before being perfectly dry, is scratched or pricked up on the surface with a hand rake made of laths; the lines are generally crossed like lattice-work, but rough.

The proportion for the scratch coat is as follows: One part quick-lime, four parts sand, and one-quarter to one-third measure of cattle or goat's hair. It is usually put on from three-eighths to one-half inch in thickness.

For Two-coat Work and Finish.—The scratch coat is generally done as in one-coat work, and worked on the surface roughly, but level with hand-floating. It is required to keep the work plumb and true, and scratched to receive the second coat, which is known by the name of *browning*. Where, as in this case, the plastering is finished with two coats, the second coat is usually one-quarter or three-eighths inch thick, and will make a very handsome finish if done with three parts clear grey or silver sand; mixed with one part *gauge stuff* or plaster of paris putty, one part *fine stuff* or lump lime slacked into a paste, and sufficient clean hair to hold in position the coat when set. This coat is thoroughly floated and troweled.

Another way is to use the same mortar, known as *coarse stuff*, for the second coat, but with less hair, and before it is dry to float it thoroughly with hand-float, brush, trowel and water, with some *gauge stuff* and a little sand, forming a skim finish. This is done in several ways, but with slight variation, the same material being used.

Three-coat Work and Finish.—Prepare wood furring by covering it with wood or metal laths. Wood laths should break joint every eighteen to twenty inches, and be laid about three-eighths to one-half inch apart. On this work the first or *scratch coat* is to be placed on the wall, and after it is thoroughly dry,

followed by the second or *browning coat;* and the third is *gauge stuff* for hard-finish. This is worked on the second coat with a trowel for one hand, and sometimes for two hands; and by using a wet brush; skilled mechanics often make very fine surfaces in this manner. This coat is usually one-eighth inch thick, and is composed of *fine stuff lime,* slacked to a paste, three parts; plaster of paris, or *gauge stuff,* one part. No more is made than can be worked up in say half an hour.

Gauge stuff is used chiefly for mouldings and cornices—the moulds beings made of zinc or sheet iron, and secured to a wooden template with handles to run the template with mouldings. For this purpose it is common to mix gradually one-third plaster of paris with two-thirds *fine stuff.* When the work can be done rapidly, equal parts may be used.

Gauge stuff is used for securing ornaments to the walls or ceilings and plaster decorations. Plasterers cast sections of ornamental cornices in lengths of about three feet, and bring them fresh to the structure, and set them in position. By this means rooms are decorated in New York and vicinity at about the same price as plain, heavy moulded cornice work can be done. The moulds that are used for this purpose are made of wax, rosin and oil, and are usually kept for use by ornamental plasterers.

Stucco finish is usually made of *fine stuff* with white sand—four parts sand, and one part fine stuff. There are other rules for stucco finish.

Less cattle hair is required in the plaster on brick walls than on laths, and usually stone and brick walls have but one strong wall coat, and on this it is finished with lime and plaster of paris, as in the last coat of three-coat work. The walls should be rough, clean and dampened.

One hundred yards of plastering will require 1,400 laths, in calculating as there is much waste, and four and a half bushels of lime, eighteen bushels of sand, nine pounds of hair, and five pounds of nails for two-coat work.

One hundred yards of plastering for three-coat work requires seven bushels of lime, one load of sand, nine pounds of hair, five pounds of nails, and 1,400 laths.

Several plasterers in New York and vicinity give the follow-

ing data: 1,000 laths will cover 666 sq. ft. One barrel of lime, one cart-load of sand, and three bushels of goat hair will scratch coat and brown coat a surface of twenty-five square yards.

Oyster-shell lime is only used for scratch coats, owing to the salt in the lime. Wood-burned lime is always the best. A great quantity of Pennsylvania lime is burned with coal, and has to be sifted, leaving often too large a proportion of *core*, which has to be thrown away. Nearly all plasterers use the lime that will work the easiest with least labor, and use materials that pay the best with labor. Thomaston or Rockland lime is used by plasterers generally in vicinity of New York. Glenn's Falls lime is very pure, and is used only in the ornamental arts.

PLASTERING.	1 INCH.	3-4 INCH.	1-2 INCH.
One bushel Cement, or 1.28 cubic ft. will cover....................	1 1-8 sup. yd.	1 1-2 sq. yd.	2 1-2 sq. yds.
One " " and one of sand	2 1-4 "	3. "	4 1-2 "
One " " " two "	3 1-4 "	4 1-2 "	6 3-4 "

One cubic yard of lime, two cubic yards of sand and three bushels of hair will cover seventy-five superficial feet of rough or scratch coat on wall, or seventy yards on lath.

One bundle of laths and 500 nails will cover about four and a half yards.

Mortar, Plaster, &c.

Stone Mortar.—Cement, 8 parts; lime, 3 parts; sand, 3 parts. *Mortar.*—Lime 1 part; sharp, clean sand, 2 1-2 parts. An excess of water in slaking the lime swells the mortar which remains light and porous, or shrinks in drying; an excess of sand destroys the cohesive properties of the mass. *Brown Mortar.*—Lime, 1 part; sand 2 parts, and a small quantity of hair. *Brick Mortar.*—Cement, 3 parts; lime, 3 parts; sand, 27 parts. Lime and sand, and cement and sand, lessen about 1-3 in volume when mixed together. *Turkish Mortar.*—Powdered brick and tiles, 1 part; fine sifted lime, 2 parts; mix with water to a proper consistency. Very useful on massive or very solid buildings. *Interior Plastering.*—Coarse Stuff.—Common lime mortar as made for brick masonry, with a small quantity of hair; or by volumes, lime paste (30 lbs. lime), 1 part; sand, 2 to 2 1-2 parts; hair, 1-6 part. When full time for hardening cannot be allowed

substitute for from 15 to 20 per cent. of the lime an equal portion of hydraulic cement. For the second or brown coat the proportion of hair may be slightly diminished. *Fine Stuff.*—(Lime putty); Lump lime slaked to a paste with a moderate volume of water, and afterwards diluted to the consistency of cream, and then evaporate to the required consistency for working. This is used as a slipped coat, and when mixed with sand or plaster of paris, it is used for the finishing coat. *Gauge Stuff* or Hard Finish is composed of 3 or 4 volumes of fine stuff and one volume of plaster of paris, in proportions regulated by the degree of rapidity required in hardening for cornices, etc., the proportions are an equal volume of each, viz., fine stuff and plaster.

Stucco is composed of from 3 to 4 volumes of white sand to 1 volume of fine stuff or lime putty.

Scratch Coat.—The first of 3 coats when laid upon laths, and is from 1-4 to 3-8 of an inch in thickness. **One-Coat Work.**—Plastering in 1 coat without finish that is rendered or laid either on masonry or laths. **Two-Coat Work.**—Plastering in 2 coats is done either in a laying coat and set, or in a screed coat and set. **The Screed Coat** is also termed a Floated Coat. Laying the first coat in two-coat work is resorted to in common work instead of screeding when the finished surface is not required to be exact to a straight-edge. It is laid in a coat of about 1-2 inch in thickness. The laying coat, except for very common work should be hand-floated, as the tenacity and firmness of the work is much increased thereby. **Screeds** are strips of mortar twenty-six to twenty-eight inches in width and of the required thickness of the first coat applied to the angles of a room or edge of a wall and also in parallel strips at intervals of three to five feet over the surface to be covered.

When these have become sufficiently hard to withstand the pressure of a straight-edge, the interspaces between the screeds should be filled out flush with them, so as to produce a continuous and straight, even surface.

Slipped Coat is the smoothing off of a brown coat with a small quantity of lime putty, mixed with 3 per cent. of white sand so as to make a comparatively even surface. This finish answers when the surface is to be finished in distemper or paper.

Hard Finish.—Fine stuff applied with a trowel to the depth of about one-third of an inch.

Cement for External Use.—Ashes 2 parts; clay 3 parts; sand 1 part; mix with a little oil. Very durable.

Asphalt Composition.—Mineral pitch one part; bitumen eleven parts; powdered stone or wood ashes seven parts.

Asphalt Mastic is composed of nearly pure carbonate of lime and about nine or ten per cent. of bitumen. When in a state of powder it is mixed with seven per cent. of bitumen or mineral pitch. The powdered asphalt is mixed with the bitumen in a melted state along with clean gravel, making it of a consistency that will pour into moulds. The asphalt is ductile, and has elasticity to enable it with the small stones sifted upon it to resist ordinary wear. Sun and rain do not affect it, wear and tear do not seem to injure it. The pedestrian in many cities in the United States and Canada can readily detect its presence on the sidewalk by its peculiar yielding to the foot as he steps over it. It is also a most excellent roofing material when rightly applied.

Asphalt for Walks.—Take two parts very dry lime rubbish, and one part coal ashes, also very dry, sift all fine, mix in a dry place on a dry day, leaving a hole in the middle of the heap as bricklayers do when making mortar. Into this pour boiling hot coal-tar; mix, and when as stiff as mortar, put on the walk three inches thick: (the ground should be dry and beaten smooth); sprinkle over it coarse sand. When cold, pass a light roller over it: in a few days the walk will be solid and waterproof.

Mastic Cement for Covering the Fronts of Houses.—Fifty parts by measure of clean, dry sand; fifty of limestone (not burned) reduced to grains like sand, or marble dust, and ten parts of red-lead mixed with as much boiled linseed oil as will make it slightly moist. The bricks to receive it should be covered with three coats of boiled oil, laid on with a brush and suffered to dry before the mastic is put on. It is laid on with a trowel like plaster, but is not so moist. It becomes hard as

stone in a few months. Care must be exercised not to use too much oil.

Cement for Tile Roofs.—Equal parts of whiting and dry sand, and twenty-five per cent. of litharge, made to the consistency of putty with linseed-oil. It is not liable to crack when cold nor melt like coal-tar and asphalt, with the heat of the sun.

Cement for the Outside of Brick Walls.—Cement for the outside of brick walls to imitate stone, is made of clean sand ninety parts; litharge five parts; plaster of paris five parts; moistened with boiled linseed oil. The bricks should receive two or three coats of oil before the cement is applied.

Mexican Method of Making Hard Lime Floors.—This method is used extensively in some parts of Northern Mexico, where they become very hard.

"The limestone used is a hard, compact blue material in some places sufficiently hard to strike fire on the drills used in quarrying it. It often contains iron pyrites in small proportions; this is calcined in kilns cut out of soft limestone. After calcination the lime is removed from the kilns and slacked as soon as cool. Part of a lot made this way was used within a day or two and part remained a month or more in barrels. All the work made with it seemed to be equally good. In making the floors a layer of broken limestone, three or four inches thick was first laid evenly over the surface of the ground. The stone being about the usual size for macadamizing roads, over this a mortar of about two parts of sand to one of lime was carefully spread to the thickness of one and one-half to two inches, this was allowed to remain for twenty-four hours; or until the surface had become quite dry. It would probably take longer in this climate, where there is more moisture in the air. The floor was then thoroughly pounded with a block of wood one foot square having a handle so that a man could stand while using it. The whole surface was beaten over with this ram until it was again as soft and moist as when first laid. This operation of ramming brought the water in the mortar to the surface, so as to form a layer of semi-fluid substance on the top. The floor was again allowed to dry: and again beaten over each day for a week when the

operation brought only slight amount of moisture to the surface. Immediately after the last pounding the whole surface was powdered with a thin layer of red ochre evenly sifted on and then polished as follows:

A smooth, nearly flat water-worn stone, a little larger than the ram was selected from the bed of a stream, and with this the whole floor was laboriously gone over; rubbing down and leaving the surface of the lime as smooth as a piece of polished stone; the red of the ochre making it of a rich brown color.

In less than a week the floors made in this way were sufficiently hard to bear the weight of a horse without indentation.

Roofs are made in the same manner; these roofs are perfectly water-tight. In the city of Monterey sidewalks of the principal streets are made in the same manner: some of them have lasted for years, wearing through like a stone. The great durability and strength of these floors and roofs is entirely owing to the pounding operation as herein described, as the same materials were tried in the ordinary way without success."

This method does not seem to have been used in this section of country.

Selenitic Mortar or Cement.—By the Selenitic process of mortar making, ordinary limes can be made into mortar that, instead of slacking with heat and considerable expansion, will have the action of cement imparted to them; with the further advantage that they will bear a larger proportion of sand than can be mixed with cements without the strength of the cement being materially affected. But as simple as the process is, it requires to be thoroughly understood or failure will be the result. This process Captain Hyde Scott, Royal Engineer of England, seems to have brought into use some twenty years ago.

In the selenitic process, ordinary stone limes, containing not less than twenty per cent. of clay—such as the lias limes of England and those which come from the lower chalk beds; for instance Dorking, Burham and Malling limes—are made to slack without heat and without expansion; to carry twice as much sand, and in a short time to attain a considerably greater degree of strength than can be got from the same limes used in the ordinary way. This is all brought about by merely adding a small propor-

tion of sulphate of lime in the shape of plaster of paris. The sulphate of lime must be brought in contact with the ordinary lime while it is in an anhydrous condition, or in other words, before the lime has been slacked. The proportion of plaster of paris required to be used is very small, about one-twentieth the bulk of the lime, if the lime contains twenty per cent. of clay. There is only one way of mixing them, and that is by mixing the requisite amount of plaster of paris, or a certain proportion of it, before the water is added to the quick-lime. Of course it is understood that the lime used must be ground.

Selenitic Clay.—Limes such as those obtained from the upper chalk formations, which contain less than twenty per cent. of clay mixed with them, require the addition of too large a proportion of plaster of paris to effectually prevent heating and expansion in the process of slacking. Consequently this deficiency has to be made good by the addition of what is called "selenitic clay," which consists of a marly clay or shale, well burned and ground to powder; as much as two bushels of this selenitic clay may be mixed with one bushel of lime.

Mixing Selenitic Mortar and Concrete.—The best method of mixing is to stir up one pint of plaster of paris in a two-gallon pail of water and empty into the pan of a mortar mill (a five-foot mill is a good size), or use an ordinary plaster tub, then add four gallons of water only; let the pan take three or four turns, and then add one bushel of prepared lime; and when reduced to a creamy paste put in the sand or other material used, and continue mixing for ten minutes. If unprepared lime is used the only difference would be that about three pints of plaster would be added to the water in place of one.

Proportion of Sand to Lime.—In ordinary mortar making, only two or three parts of sand can be advantageously mixed with one of lime; and the larger proportion of sand only with the purer limes: whilst with the selenitic process, we find from four to six parts of sand to one of lime gives the best and strongest results, but the lime for this process should be ground as it can be worked better: if it is not convenient to have it ground then make as before mentioned.

	Thrusting stress.	*Tensile stress.*	*Pulling two bricks apart.*
Common Mortar: 1 Lime, 2 Sand, ...	917 lbs.	116 lbs.	134 lbs.
Selenitic Mortar: 1 Lime, 6 Sand,........	*1657 lbs.	† 360 lbs.	‡ 329 lbs.

* Base area 7.84 square inches.

† Section area 5 square inches.

‡ Area of point of contact equal 18.5 square inches.

EXPERIMENT MADE WITH LEE'S DURHAM (ENGLISH) LIME.

Concrete Construction.—On the Chester sewage works, England, in reference to the construction of Tanks, the *Engineer* states: "Cement concrete has been resorted to as a substitute for brickwork; and as a substitute it may succeed well enough provided the persons engaged in the performance of the work have had experience in the use of the materials and take a personal interest in their work."

First, as to the Cement Concrete.—The concrete was said to have been composed of the following measured proportions: gravel six parts, sand one part, cement one part. If the cement was reliable these proportions ought to result in first-class concrete. I prefer the Lias cement if properly manufactured—it is made of the Lias limestone of Warwickshire.

Second, as to the Lime Concrete.—This was understood to have been made in the following measured proportions: gravel five parts, sand uncertain and variable but in small quantities, Rugby or Holywell ground lime one part. These proportions formed a rich concrete which may have been improved in its final hardening properties by a larger proportion of sharp sand. I prefer also that the lime and sand shall be made into a well mixed mortar before being added to the gravel. The strength of all concrete depends on the intimate blending of angular sand with the cementitious matter, for without that a proper crystallization is not obtained.

Third, as to the Mortar.—This was stated to consist of: lime two parts and sand two parts, cinders one part. This was not a good material. The sand was in fact crushed sandstone, and the cinders were really slags of steam boilers. These were ground with the lime under edgestones until the whole was reduced to an impalpable mixture, rather like limey mud. The sand should have been sharp and angular, the cinders should

have been smith's ashes, containing the usual proportion of iron oxides. Hand made or well pegged mortar is to be preferred for engineering purposes to finely crushed mortar.

ANCIENT CEMENTS.

Abstract of Article by Arthur Beckwith, C. E.

"* The monuments of Egypt present one of the oldest examples of the use of lime for constructions. The mortar which joins the stone of the Pyramid of Cheops is precisely similar to modern mortars made of sand and lime. In limiting the use of mortar to filling narrow joints which separate immense blocks, and thereby reducing almost to insignificance the part which it has to play, the Egyptians seemed to forestall the influence of a dry and burning climate. Time has justified their prudence in this respect, for the works erected on the banks of the Nile by the Romans, made of small materials and presenting many joints, have left but faint traces, whilst some Egyptian temples still present themselves intact to our admiration.

Unqualified praise has often been given to the excellence of Roman mortar, and the belief is sometimes expressed that all we can hope to do is to regain the secret of making mortar once possessed by the Romans. It is a common remark that "Roman mortar has lasted for eighteen centuries, whilst a number of modern buildings are in a deplorable state of preservation."

To make a fair comparison, we should, however, only cite similar constructions, and then we are comforted by these words of Pliny: "The cause which makes so many houses fall in Rome, resides in the bad quality of the cement."

The knowledge of the properties of lime descended from Egypt to Greece, where the exigences of the climate and the ingenuity of the people brought forth many of its uses, unknown to Egypt.

Subsequently Greek colonies imported and popularized their processes in Italy; and Roman architects, like Vitruvius, cite the names of Greek authors on the art of construction. Their names alone have come down to us, but Vitruvius had full access to them, and in our inquiry after the knowledge of mortar pos-

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* **From the proceedings of the American Society of Civil Engineers.**

sessed by the Romans, it is to him that we must refer for information. Indeed, he has left us a detailed table of precepts used by the builders of Greece and Rome, which do not justify our unreserved admiration; everything relating to lime, sand and pozzolana is clearly treated therein.

We may safely affirm, with Vitruvius, that the Romans made use of the lime, sand and materials of the countries where they built; that they considered the best lime to be produced from hard and pure marble, *i. e.*, the fattest lime known; that in Italy they mixed it with pozzolana when used for hydraulic purposes, and that out of Italy they replaced the pozzolana from Vesuvius, by powdered brick or tile.

Roman mortars, when examined today are found to bear a distinct resemblance to each other; they may be recognized by the presence of coarse sand mixed with gravel; lumps of lime are so often to be met with, that incomplete slaking will alone account for them. Mortars laid in damp spots for cisterns and pavements were composed of bricks in small fragments mixed with fat lime; this concrete required to be compacted by pounding and left to dry—the surface was then scraped, polished and painted—evidently to prevent the dissolution of lime by water.

It will be seen by this that what we term hydraulic lime, and also the modern product of cement, were unknown to the Romans.

It is important to refute the belief that methods may have been known to them of which we have lost the secret. When the decay of arts followed upon the downfall of the Roman Empire, houses nevertheless continued to be built, and the familiar processes under the eye of the workman must have been transmitted from father to son. So true is this, that today Italian masons, who certainly have not read Vitruvius, make coatings for cisterns and concrete floors in the very same manner as may still be seen in the ancient ruins of Rome.

Neither is it true that Roman mortar is uniformly good. Its strength of cohesion varies in different examples from 35 to 85 lbs. per square inch to 100 and 160 lbs., or as much as 500 per cent.

In the middle ages a volcanic conglomerate from the banks of the Rhine, named traass, was substituted for the pozzolana

of Italy, and mortar was made of fat lime, mixed with traass, to render it hydraulic.

Many castles erected during that period stand well today; the well-known castle of the Bastile, erected in 1369-83, which after withstanding a siege required the use of powder for its destruction in 1789, was found to be extremely solid even in the interior walls.

It would seem, then, that the secret of the Romans was known also in those times, and could have been lost only at the Renaissance, when least of all such a supposition is probable.

At what period were first used certain limestones, having the property of producing a lime which will harden under water; it is not precisely known; the first use of cement stone is equally obscure.

In 1796 Messrs. Parker and Wyatts began to manufacture from egg-shaped limestones found near London, a product known later as *Roman Cement*, and which was soon received with great favor throughout Europe; but neither the producers nor the consumers offered any explanation of its merits.

Not until 1818 and the following years was the true explanation given to the hydraulic properties of limes and cements, when Vicat published his discoveries.

Before that, in 1756, when Smeaton was preparing the arduous and bold construction of the Eddystone Lighthouse, this celebrated engineer examined with scrupulous attention the natural hydraulic lime of Aberthaw. Treated by acids it left a residue "which appeared to be a bluish clay, weighing about one-eighth of the total weight of the stone."

In 1786, Saussure attributed the hydraulic properties of some limes of Savoy to the combined influence of manganese, quartz, and even clay; but he left his opinions in the mere state of conjectures.

Finally, Descostils, in 1813, having discovered a considerable proportion of finely divided silica in the lime of Senonches, attributed the well known hydraulicity of that lime to the silica it contained.

But the conjectures of Smeaton, of Saussure and of Descostils were vague; they rested upon no proofs, and found no applications in practice.

The discoveries of Vicat attained their immediate object, for in a short time artificial hydraulic lime of excellent quality was manufactured on a large scale under his direction, and a few years later he indicated as many as 400 quarries in France where hydraulic limestones were to be found.

The following valuable selection is from an English journal:

Rapidity of Set.—Very rapid setting and great strength are not met with in the same cement; but in many cases the quicker setting and lighter cements are most useful. It is believed that before long light Portland cements will be manufactured, capable of competing with the Roman cements, in quickness of setting, and surpassing them in uniformity of quality.

The following table contains the result of a series of experiments made by Mr. J. GRANT, C. E., London, England, with Portland cement, weighing 123 lbs. per bushel:—

Average Breaking Test of Ten Specimens.

Age.	Neat Cement.	1 Cement, 1 Sand.
	lbs.	lbs.
7 days	817-1	353-2
1 month	935-8	452-5
3 "	1055-9	547-5
6 "	1176-6	640-3
9 "	1219-5	692-4
12 "	1229-7	716-6
2 years	1324-9	790-3
3 "	1314-4	784-7
4 "	1312-6	818-1
5 "	1306-8	821-0
6 "	1308-0	819-5
7 "	1327-3	803-6

The whole of the specimens were kept in water from the time of their being made up to the time of testing, and the breaking weight applies to a sectional area of 1 1-2 inches square, or 2.25 inches super. It appears from these experiments that neat cement of 123 lbs. per bushel took two years to attain its full strength, whilst the admixture of sand, in addition to weakening the specimens, also delayed their attaining their maximum powers of resistance.

Color.—A dull earthy color denotes an excess of clay; whilst tool ight a color is the result of either under-burning or an excess of lime, or of both these faults combined.

Packing the Cement.—Since Portland, unlike Roman cement, improves within certain limits by exposure to the air, it need not be packed in air-tight casks (except for exportation), but kept dry. The casks in which it is packed generally contain four cwt., and the bags two cwt.

Water for Mixing.—Salt water does no injury to the strength of the cement, but must be avoided where efflorescence or damp on the surface would be objectionable.

Both cement, mortar and concrete should be made with as little water as will suffice to make the whole cling together. When too much is used, the finer particles of the cement get separated from the rest and float away, or on the surface in the form of a slime. In mixing concrete, if the ballast is porous and dry, more water will be required than if damp or non-absorbent.

Sand, Gravel, and other Materials for Mixing with Portland Cement.—Experience has shown that porous materials, by allowing the cement to enter the pores, and so retain a firm hold on them, are the best for mixing with cement: thus, well-burnt broken bricks, clay ballast, furnace slag or breeze, will form a stronger concrete than if made with the harder but smoother and less porous stones in gravel or shingle; but it must be borne in mind that in such cases a slightly larger proportion of cement is advisable to compensate for what is absorbed by the pores of the material. No importance need be attached to the shape of the particles of sand or other materials used—such as whether angular or water-worn—though a certain roughness of surface gives a better hold to the cement than if too smooth. The presence of dirt, such as loam, clay and vegetable matter liable to decay, has a prejudicial effect upon cement, and sensibly weakens either mortar or concrete.

The gravel, broken stone, or other material used in making concrete, should have sufficient small stuff and sand mixed with it to fill up the interstices between the larger pieces. When this is not already the case, the amount of small stuff and sand

which ought to be added may be ascertained by filling up any suitable measure, of uniform section from top to bottom, with the gravel, &c., striking it level with the top, and then adding as much water as the measure will contain. The water may then be run off through a hole in the bottom of the measure, the gravel, &c., removed from it, and the water replaced in it; the amount of water expressed in terms of the internal height of the measure will be the proportion of small stuff which should be added to the ballast.

Proportion of Cement in Mortar and Concrete.—As cement is not used, on account of the cost, unless special strength is required, the proportions in general use are 1 cement to either 1 or 2 sand; below this the advantage gained by its use diminishes rapidly. In general terms neat cement is one-third stronger than if mixed with 1 sand, and twice as strong as when mixed with 2 sand.

For concrete, 1 cement to 10 or even 12 gravel, or other material, is sufficient for masses in foundations, dock walls, &c.; 1 to 8 or 6, for ordinary walls, according to their thickness; and 1 to 4 for floors, and other places where great transverse strength is necessary.

Mixing and Laying Portland Cement Concrete.—The best method of mixing concrete in large quantities is, taking a measure of convenient capacity for one mixing, to half fill the measure with the broken ballast, or other material, and then add the cement; finally filling up the measure with the ballast. The measure should then be lifted off, when the whole will fall into a heap, the cement partially mixing with the ballast in so doing, and not being so liable to get wasted by being blown about by the wind, as when emptied over the top of the ballast heap. The whole should be turned over twice dry, and then shovelled to a third heap, sufficient water only being added in so doing—by sprinkling from the rose of a watering-pot—to make the ingredient cling together in a pasty mass. The floor upon which it is mixed should be hard and clean.

The concrete may either be wheeled off and deposited in position, or, if more convenient, may be thrown down, but in both cases, more especially in the former, it is advisable to beat it

down lightly with wooden beaters until the moisture comes to the surface.

On no account should it be sent down a shoot, or the finer and coarser ingredients will get separated in the descent, the former clinging more to the sides of the shoot, whilst the latter will reach the bottom first, and get shot out into a heap by themselves.

Not to be disturbed whilst Setting.—When cement-work has once been laid, it must not be touched until quite hard, for its strength will be materially affected if the particles are disturbed after the process of setting has commenced.

Bricks, Stones, &c., to be Wetted.—All absorbent surfaces or materials, with which cement is to come in contact, should be well wetted, or they will rob the cement of the moisture necessary to enable it to set hard; but the water should not be oozing out of them, or the cement, being unable to enter their pores, will fail to adhere properly to them. For this reason broken brick ballast, &c., if quite dry, will require more water in concrete making, than if already damp, and old dry walls will require more wetting than new or external damp walls.

Cement to be kept Damp while Setting.—Cement-work must be kept damp until set quite hard, or it will become rotten from the evaporation of the water of mixing, which is essential to the proper setting of the cement: hence the most suitable time for executing cement-work is in damp weather. When the work has to be done in dry weather, special care is necessary to keep it damp, and to protect it from the sun's rays. Flat surfaces, such as floors, paving, &c., should, if practicable, be kept flooded with water or covered with a layer of sawdust or sand 3 or 4 inches thick, which should be kept quite damp for at least seven days, or until the cement has become quite hard. In surfaces exposed to traffic this is most important, as the cement, if at all perished, will soon wear away.

Avoid imbedding Iron in Cement.—Cement mixed with sand and other materials is porous, admitting both moisture and air; iron, therefore imbedded in cement-work, is liable to rust, and

the expansive force accompanying this process will split up cement, stone, or any similar unyielding material; if the iron is galvanized it is not affected by the cement.

Description of Portland Cement.

Characteristics of good Portland Cement.

The following explanations about the uses of Portland cement will apply to a great extent to all other cements.

1. **Fineness.**—It should, when passed through a copper wire sieve of 2,500 meshes per square inch, not leave more than 20 per cent. of grit behind. The cement sifted should not be less than 25 lbs., taken from different bags, or from different parts of the heap if stored in bulk. After a little experience, a well-ground cement may readily be recognized by the absence of grit when rubbed between the fingers.

2. **Expanding or Contracting in Setting.**—When made up without sand or excess of water, and filled up level with the top of a glass or similar vessel, it should set hard without cracking the vessel, rising or sinking, or getting loose in it, or showing any signs of cracks in the cement itself.

3. **Strength.**—When made up without sand, with as little water as possible, and filled into moulds, it should, after seven consecutive days in water, give an ultimate strength, under a tensile stress slowly applied, of 250 lbs. per square inch of fractured section, the immersion in water to commence as soon as the cement blocks will bear removing from the moulds, which should not exceed twenty-four hours after the moulds have been filled.

When time will not admit of this test being applied, a very fair idea of the strength of the cement can be arrived at from its *weight*, which should not be less than 108 lbs. per imperial striked bushel, filled up as lightly as possible, by pouring the cement down an inclined board, or through a wooden hopper, about 1 foot square at top, 1 inch square at bottom, and 1 foot deep. The hopper should be suspended with the point of discharge 6 inches above the top of the bushel measure, which should stand

on a firm base and not on any vibrating floor, and should not be touched until the cement in it has been finally struck level with the top with a straight-edge. The cement weighed should be taken from different bags, or from different parts of the heap if stored in bulk.

Rapidity of Set.—When made up into cakes about half an inch thick, without any sand or excess of water, the cement should set hard within 24 hours, either in or out of water, without showing any signs of cracks.

Color.—The color of good Portland cement is a bluish-grey; if dark and earthy, or of too light a color, it is not to be trusted. When made up without sand and set hard, it should show the same bluish-grey color without any brown specks or stains.

Explanatory Remarks.

Fineness.—A high degree of fineness is necessary to the complete and simultaneous setting of all the particles throughout the mass. When insufficiently ground, the fine particles set first, then the coarser grit, and lastly the little hard lumps; and it is this process going on, after the surrounding particles have already set hard, which often shows itself all over the surface by the "blowing" or bursting out of numberless pustules, or the cracking of the entire body of the cement.

Some foreign cements allow of 85 per cent. passing through a No. 60 gauge, or 3,600 meshes per superficial inch; but cements of such extreme fineness are under-burnt, and therefore weigh light, and are deficient in strength, though often rapid in setting. The wear and tear to the machinery in grinding well-burnt cements to such extreme fineness would render them too costly to be marketable.

Expanding or Contracting in Setting.—The test for expansion or contraction in setting is very simple, and one which should on no account be omitted, for these are about the most serious defects to which Portland cements are liable, though for the most part no steps are taken to guard against them.

Expansion in setting is due to the presence of free lime in the cement—owing either to more lime having been used in its man-

ufacture than can chemically combine with the clay—to imperfect mixing of the lime with the clay, or to the burning not having been carried to a sufficient extent to enable the lime and clay to combine together.

Contraction in setting, which is not nearly so often met with, is due to an excess of clay, and, as there is no remedy for this evil, the cement must be rejected.

The tendency to expand in setting is a very common fault in fresh-ground cements, especially those of the heaviest and strongest descriptions, owing to the large proportion of lime used in their manufacture, which, if in excess, as already explained—or even locally in excess, owing to imperfect mixing—is present in the cement in the form of free lime, which heats and expands considerably in the process of slaking. However, if the cement is otherwise good, this evil can be remedied by spreading it out on a dry floor, under cover, and turning it over occasionally, to allow of its air slaking or "cooling."

"When delivered on the works for use, Portland cement should always be shot from the bags on to a wooden floor—to a depth not exceeding 4 feet—and be permitted to remain at least three weeks before it is allowed to be used for *any* purpose. While so kept, fresh Portland cement increases considerably in bulk—probably 10 per cent.—without any diminution of its strength; so that it should be to the advantage of a contractor to store his cement before using it, even if he were not required to do so by the engineer. I can hardly impress too strongly upon you the importance of avoiding the use of fresh cement for any purpose whatever."

Many a good, strong cement which, when first delivered, would heat in mixing and expand in setting, would, after exposure to the air for a time, stand the test for expansion perfectly.

Tests of Cements.—F. O. Norton, Civil Engineer, who has made a large number of experiments on American cements, has obtained a class of comparative results, which gives a clear knowledge of the magnesian limestone. The principal deposit of the magnesian limestone producing a cement possessing hydraulic energy, occurs in the town of Rosendale, Ulster Co.,

New York. The following tests were made at the works at Binnewater, during the season of 1878, commencing in April and continued for eight months.

Several times each day a number of briquettes were made of the cement manufactured that day. The briquettes were mixed in two ways—in one the cement was mixed with water to form an ordinary stiff mortar, which was pressed in the moulds and smoothed off: for the other a very dry mixture was made. Both mixtures were left in the moulds a few minutes, and were then pressed out with a wooden plunger, and left in the air thirty minutes. They were then put in water and left in water until broken. 5824 briquettes were made and broken during the eight months.

RESULT OF TESTS.

Tensile strength per square inch, represented in pounds on 5824 Briquettes.

	15 days	*1 mo.*	*2 mo.*	*3 mo.*	*4 mo.*	*5 mo.*	*6 mo.*	*7 mo.*	*8 mo.*	*9 mo.*	*10 mo.*	*11 mo.*	*12 mo.*
1878. Stiff Mortar,............	65	170	265	385	395	425	440	454	475	465	470	465	464
" Dry Mixture,...........	150	230	300	350	380	405	410	415	415	415	405	405	405
1879. Stiff Mortar, ...	125	250	380	460	500	520	530						

The briquettes were shaped like a dumb-bell the breaking area being one inch square.

Rosendale cements of the best qualities develope great hydraulic strength in twenty-four hours, being at that time equal to Portland cement. The Portland cement gains rapidly up to seven days, at the end of a month the Rosendale approaches the Portland and the difference between the two is changed after that time.

For practical purposes all cements are generally used with a mixture of sands. This reduction of strength in round numbers is as follows:

1 part	of	sand	gives	mortar	1-2	as strong	as pure	cement.
2	"	"	"	"	1-2	"	"	"
3	"	"	"	"	1-4	"	"	"
4	"	"	"	"	1-5	"	"	"
5	"	"	"	"	1-6	"	"	"

The following Tests of Cements were made in the months of Jan., Feb. and March of 1882.

THESE TESTS WERE MADE IN NEW YORK.

Brand.	Mills B'ld'g.	Time.	Dry.	Wet.	Time.	Dry.	Wet.	Time.	Dry.	Wet.	Time.	Dry.	Wet.	Tensile strain of lbs. per square inch. / Remarks.
Swedish,	"	24 h.	80	72	7 days	194	190	14 d'ys	257	160	21days	304	306	Imported is
Gillingham,	"	24 h.	78	92		329	240		308	448		390	424	very good.
Burham,	"		50	62		318	386		220	200		278	292	
Dyckerhoff,	"		70	80		262	204		230	240		217	235	
Delafield,	"		56	48		128	118		214	205		280	200	The longer
Laurenceville,	"		50	36		72	56		138	130		85	60	it stands the
Rock Lock,	"		80	32		233	47		206	f'il		210	78	better it is.
Connelly & Scheffer,	"		40	24		80	70		98	101		95	46	

All these cements are in use in the city of New York. Small moulded pieces of cement of the form of a dumb-bell were cast with the middle part 1 inch square. Each one of these forms were tested separately on scales made for testing building materials.

Hydraulic Limes and Cements.—If limes harden under water in from fifteen to twenty days after immersion, they are slightly hydraulic; if from six to eight days, simply hydraulic, and from one to four days, eminently hydraulic. Hydraulic limes if not properly slacked, will sometimes burst. It should all be hydrated before placing, which will require more time than ordinary lime. The different kinds act differently. There is but little heat developed in these limes while slacking.

The hydraulic lime of Tiel, manufactured in France, and imported to this country in barrels of from 450 to 600 pounds, is extensively used, and considered a very strong cement. It will set firmly in eighteen to twenty-four hours under water, and increases in tensile strength from 40 to 160 pounds per square inch, and the crushing weight from 200 to 600 pounds per square inch. It weighs from 40 to 45 pounds per cubic foot. The slacking of 100 pounds of Tiel lime requires 28 pounds of water.

For Salt-Water Mortars, Concrete under water.—One part of Tiel lime to two parts of sand.

For Mortars Exposed to Air.—One part lime, three parts sand.

To form Betons and Concrete from the Mortars before mentioned.—*Salt-Water Concretes.*—Two measures of mortar, thoroughly mixed with three of broken stone.

Fresh-Water Concretes.—One measure of mortar to two of broken stone.

Artificial Blocks.—One measure of mortar to two of pebbles.

Portland Cement is made of argillaceous limestones selected for the purpose, or argillaceous chalk or calcerous clays, or mixtures of artificial carbonate of lime or clay, and artificial mixtures of caustic limes and clay.

It is burned in kilns with a heat of sufficient duration and intensity to produce the beginning of vitrifaction. After this the product is ground to powder. There should be from seventy to eighty per cent. carbonate of lime, and twenty to twenty-five per cent. of clay, and not less than ninety to ninety-five per cent. of the lime and clay required for a first quality cement. Hard carbonates of lime are expensive to reduce to powder, yet hard limestones may be used. Suitable clay is of more rare occurrence than suitable limestone, for the reason the former must contain alumina and silica, not only in certain proportions but in a certain state of pulverization.

For foundation walls on damp and yielding soils, also for submarine masonry, Portland cement concrete is superior to brickwork in strength, durability and economy. It is also well suited for sewers, piers, abutments, pavements, etc. A barrel weighs about 400 pounds, and has a tensile strength of 250 pounds per square inch, and safely sustains, after seven days set, 470 pounds per square inch.

Concrete or Beton is a mixture of lime, sand and gravel or broken stone, or hard-burned broken brick. When cement is used instead of lime, it is known as a cement concrete.

The object to be attained in making hydraulic concrete is to give such a sufficiency of mortar as will produce the aggregation of the whole mass of rough rubble materials.

When Portland cement is used, one part of cement may be used to three parts of sand, and this may be mixed with six parts of gravel, stone, spalls or broken bricks.

For Tiel lime, lime three parts, sand five parts, two parts broken stone. This is at it was used at the mole in Marseilles.

The French Beton Agglomere.—Cement in blocks consists of 180 parts of sand, 44 parts of lime slacked, 33 parts of Portland cement, and 20 parts of water. This is most thoroughly incorporated.

Vicat Cement.—This artificial cement sets strongly in from eight to fifteen hours, and is able to stand great cold. Vicat mortar, of one part of cement to three parts of sand, when fourteen days old, sustained safely a pressure of 300 pounds per square inch.

Lafarge Cement—Weighs sixty-six pounds per cubic foot. Begins setting after three to three and a half hours; completes its setting in twelve to eighteen hours.

Made into Mortar.—One part cement to two parts sand. After eight days setting, its tensile strength was found to be 142 pounds per square inch.

Made into Mortar.—One part cement, three parts sand. After three days setting, did not crush until loaded with 81 pounds per square inch. The same mixture,

After 13 days	540	pounds	square	inch,	crushing	load.
" 33 "	942	"	"	"	"	"
" 48 "	1049	"	"	"	"	"

In practice it would be safe to use a working load to the above of one-quarter of the crushing load.

The resistance to rupture after twenty days exposed to the air, is about 54 pounds per square inch; with equal proportions of sand and cement it falls to 27 pounds.

American and Foreign Cements.—

American Rosendale	from	60 to 70	pounds	cubic foot.
English Portland	"	95 to 102	"	" "
And in barrels	"	400 to 430	"	to barrel.
French Portland	"	95 to 105	"	cubic foot.
Lafarge	"	66 to 70	"	" "
Tiel Lime	"	52 to 58	"	" "

The following cements were made into small blocks, four inches square by one inch thick, and they set as follows:

Statine, French Cement	15 minutes.
Pomeranium, German	13 "
K and S Portland, imported	11 "
White's " "	7 1-2 "
Rosendale, U. S.	30 to 45 "

They were tested by tapping them with a piece of wood, the size of a common clothes-line pin; when no impression was made, they were said to have set.

Keene's Cement.—An imported cement, is used extensively for interior decorations, artificial marble cornices and center-pieces. The superfine is of a delicate white, takes a high polish, and makes beautiful scagiola-work. There is a medium quality used for the same purpose, and used in artificial marbles. The coarse is used for stucco, and has great durability; also for floors to halls, areas, passages, vestibules, churches, etc. It is less expensive than Portland cement. One cask contains four bushels, which, mixed in the proportion of one part cement, and two parts sand, will cover about fifteen superficial yards one-half inch thick.

For Polished Work of Walls.—Use the floating coat of equal parts Keene's coarse cement and sand; the setting coat to be of superfine one-quarter inch thick.

For Stucco on Brickwork.—For floating coat, one part cement, and two parts sand. The setting coat should be three-sixteenths inch thick.

Where it is required to lay a coat of cement over a floor surface, one barrel of Portland cement, weighing about 400 pounds, if used neat, will cover five square yards of surface one inch thick; and when mixing, if there is added two parts of sand, it will cover fifteen square yards of surface one inch thick.

Rosendale Cement Concrete.—One barrel Rosendale cement, (300 pounds weight, 75 pounds per bushel;) three barrels of sharp, gritty and damp sand; five barrels of broken stone; will sustain a load of 40 pounds square inch when set.

Portland Cement Concrete.—One barrel of Portland cement, (400 pounds, say five cubic feet;) one barrel of Thomaston lime, eight barrels of sand, twelve barrels of broken stone; will sustain a load of 50 pounds per square inch when set.

Rosendale cement weighs about 75 pounds per bushel; Portland cement will average 116 pounds per bushel, when 90 per cent. fine. Dark cement appears to be the strongest. Fine quality cements are now manufactured in many parts of the United States. The best are from Rosendale cements of New York and New Jersey; Cumberland, Maryland; Round Top, Hancock, in Maryland; Sandusky, Ohio; and Shepherdstown, Virginia.

Nearly all hydraulic limes and cements, after being packed in barrels, will lose their energy by exposure or age.

The imported Boulogne Portland cement, after getting a permanent set, will sustain a load of 1000 pounds per square inch. Its tensile strength is 340 pounds per square inch. It is most desirable for strong masonry, wharves, piers, foundations, sewers, etc., and concrete sidewalks. It takes several hours to set.

For Mortar of Great Strength—One part Boulogne cement, five parts coarse sand.

Selenitic Lime or Cement—Is prepared by mixing and grinding together unslacked high-degree hydraulic lime and calcined plaster of paris, in the proportion of ninety per cent. lime and ten per cent. plaster of paris. When made into mortar with sand it sets quickly and firmly, and can be used for concrete of mason's work; is durable and very firm and strong. The only selenitic process cement used in this country is the Howe's Cave cement, New York.

For certain purposes the natural light cements, and those manufactured in the United States, possess sufficient strength for the purposes to which they are applied: For massive concrete foundations and walls, for the backing of thick walls faced with ashlar, and for giving hydraulic energy to mortar for stone and brick masonry, there are several high grades of Portland, New York and Pennsylvania, equal to those imported from Europe.

Cement Mortar for Brick-laying.—One part cement, two parts sand. *For Stone-work, ordinary*—One part cement, three parts sand.

Mortar of Cement.—One barrel of cement, say 300 pounds, two barrels of sand, one-half barrel of water, will make say eight

cubic feet of mortar, and will lay 500 bricks, or one cubic yard of rubble stone-work. Three or four more parts of sand may be added, according to quality of work.

Cement Mortar for Stone Masonry—*i. e., Cut or Squared Mason Work.*—One cask of cement, say 300 pounds, ninety per cent. fine; one-half cask lime, *Thomaston;* fifteen cubic feet of sand.

The mixing of lime with cement makes the cement set slower, and is also cheaper.

Cement Mortar for Brick Masonry.—One cask of cement, one-half cask of lime, four cubic feet paste, and ten cubic feet of sand.

Where cements are used on masonry of railroad work, the proportion of mortar is one-third of cement to two-thirds of sand, and sometimes lime is added.

Ordinary Concrete.—One part cement, one part lime, two parts sand, and four parts granite spalls or shingle.

Brickdust Cement Concrete.—One measure or part of new lime, one and one-quarter measures of part brick or tile dust, one and one-quarter measures of parts of sand, five measures or parts of broken stone, and water.

Lime and Cement Concrete.—One-half bushel cement, three-eighths bushel lime, two bushels sand, four bushels broken stone, and three-eighths bushel water.

Lime should always be slacked a day or two before mixing the concrete.

TABULAR STATEMENT OF TESTS MADE ON HYDRAULIC AND OTHER CEMENTS AT THE CENTENNIAL EXHIBITION, PHILADELPHIA.

All these cements were tested by mixing them dry, in every case with equal quantity of clean sand, tempering it to the consistency of stiff mason's mortar. Then they were moulded into

small bricks, equal to two and one-quarter square inches of surface, allowed one day to set in the air, and placed in water for six days. After a number of trials on each, the result was divided by two and one-quarter to get the load on each square inch.

CEMENTS.	*Crushing strength per square inch.*	*Tensile strength per square inch.*
Stettin, German, Portland Cement	1,436	206
Hollick's Portland, London, England	1,300	212
Wouldhan's " " "	1,150	200
Saylor's Portland, Allentown, Penn., U. S.	1,078	184
Portland Wampum, New Castle, Penn., U. S.	968	168
Pavin de Lafarge, Tiel, France	931	158
A. H. Lavers', London, Eng., Portland	926	192
Francis, Portland	907	163
Mc Kay, Ottawa, Canada	882	141
Delfzyl, Netherlands	826	132
Longuety & Co., France	764	108
Riga Cement Co., Riga, Russia	693	134
Scanian, Sweden	606	112
Estland, Russia	580	154
ROMAN AND OTHER CEMENTS.		
Coplay Hydraulic, Pennsylvania, U. S.	292	38
Manlius, New York, U. S.	276	47
Seigfried Bridge, Pennsylvania, U. S.	276	43
Gauvream, Quebec, Canada	234	47
Riga, Russia	230	44
Cumberland Hydraulic Cement Co., Maryl'd, U. S.	200	42
Societe Anonyme, France	184	29
Anchor Cement, Allentown, Penn., U. S.	201	42
Howe's Cave Association, New York, U. S.	184	42
Societa Anonima, Emelia, Italy	180	27
Gowdy, Ontario, Canada	126	24
Lavers, London, Eng	122	25

There would naturally occur many reasons for the above tests being variable, owing to the selection of cement for the test, and exposure to the heat of the sun, etc. Most of the above data was obtained from nine to twelve tests on each kind of cement. Thirty-three per cent. of the test would give a fair working load for foreign cements, and forty per cent. for the United States, as every year great improvement is being made in the manufactures of all grades of cement in this country; and the tests are open to such criticism, owing to competition and use here, that they may be relied upon.

When Portland cements are made into blocks without sand and filled in moulds, and turned out after twenty-four hours, they may then be immersed in water, and at the expiration of

eight days they will give a tensile strain, slowly applied, of 250 lbs. to the square inch.

On Cements.—Mr. F. Collingwood, Civil Engineer, has made a number of exhaustive experiments at the East River Bridge, N. Y., on cements. He states, that in mixing water with cement, the quantity of water used was limited to produce the best result. This varied with every lot of cement, even from the same maker. That which in one case would make a clean, hard briquette, would in another not give any coherence when rammed. The percentage of water is given in the annexed table, this was sufficient to make the mass slightly moist; after this it was rammed in the moulds. About one-half more water would, in each case, give a mortar of the right consistency for use. The sieve used had 2500 meshes per square inch. There were forty individual tests: ten tests for twenty-four hours, ten for seven days, ten for fourteen days, and ten at twenty-one days' setting; the briquettes being made at the same time and from the same barrel. The briquettes were 2 x 1 1-2 in the breaking section, with ends enlarged to fit the clamps in the testing machine. In compression a portion of the same specimen was crushed, the size was 2 x 2 x 1 1-2. The twenty-four hour tests are no criterion as to the ultimate strength of cements. Further tests were made to compare brick for tensile and compressive strains, but it is stated they were not very satisfactory; yet here is the result.

Haverstraw brick were used, not the hardest.

Of whole bricks, 10 tests, set on end,	compression	averaged	2,065 lbs.	per	square	inch.
10 half bricks on side,	"	"	4,612 "	"	"	"
10 " " flat,	"	"	3,371 "	"	"	"

These tests seem to compare favorably with a table of tests also made in New York, see page 81. Twelve bricks were carefully cut to fit the cement-testing machine. The tensile strength averaged ninety pounds per square inch. All of these experiments when they are properly done, give the preference to well and carefully laid full size, hard-burned brick over cement.

COLLINGSWOOD ON CEMENTS.

CEMENT TESTS; EAST RIVER BRIDGE—NEW YORK.

	Air Tension.				Air Compression.				Water Tension.				Water Compression.				Fineness.	Water, pr. ct.
	Time. Days.				Time. Days.				Time. Days.				Time. Days.					
	1	7	14	21	1	7	14	21	1	7	14	21	1	7	14	21		
Saylor's Portland,	115	205	216	218	1168	1803	1700	1747	80	174	191	250	1146	1698	1621	2025	96	18 to 23
" Excelsior,	111	110	156	187			1405	1770	19	94	142	161	210	950	1255	1275	98	25
Coolidge Portland,																		
Newark Lime &									77	192	197	227	840	2365	2448	3377	90	25 to 30
Cement Co.,	67	80	97	97	115	1042	790	1448	22	76	71	78	400	882	640	1014	98	25
Lawrenceville,	91	119	137	208	770	900	1266	2226	65	65	79	108	555	475	957	1767	90	25 to 30
Ramsey,	39	60	74	60	180	532	656	902	29	39	37	25	135	455	358	286	89	28
N. Y. & Rosendale,	57	99	109	153	397	900	693	1330	48	53	58	82	305	374	332	1275	81	23
F. O. Norton,	65	148	151	180	592	1902	1875	1887	58	75	104	121	713	1487	1275	1562	97	25
Round Top,	79	123	102	159	606	755	1094	2495	74	72	83	94	620	480	889	2115	87	22

Roman Cement.—Slacked lime one bushel, green copperas three and one-half pounds, fine gravel sand one-half bushel. Dissolve the copperas in hot water, and mix all together to the proper consistency for use; use the day it is mixed and keep stirring it with a stick while in use.

Vicat's Hydraulic Cement—Is prepared by stirring into water a mixture of four parts chalk and one part clay; mix with a vertical wheel in a circular trough, letting it run out in a large receiver. A deposit soon takes place which is formed into small bricks, which after being dried in the sun are moderately calcined. It enlarges about two-thirds when mixed with water.

Hydraulic Cement.—Powdered clay three pounds, oxide of iron one pound; and boiled oil to form a stiff paste.

Stone Cement.—River sand twenty parts, litharge two parts, quick-lime one part; mixed with linseed-oil.

Glue.—Powdered chalk added to common glue strengthens it. A glue which will resist the action of water is made by boiling one lb. of glue in two quarts of skimmed milk.

Cement Mortar.—If one measure (slightly compacted by shaking,) of ground cement be mixed with about one-third of a measure of water, it forms about two-thirds of a measure of paste fit for mortar. Perfectly fresh cements require a little

more water than old, and cements differ among themselves as to the proper quantity of water. If sand is to be added, more water will of course be needed, but this should be added in very small quantities as the mixing or tempering goes on, inasmuch as a much less quantity is required than would at first sight be supposed. So also on the addition of lime, as before remarked, the pure cement is stronger without any addition whatever of either lime or sand; still it will be quite strong enough for most ordinary purposes, especially when not exposed to water, even with a considerable addition of both. But if it is to be exposed to absolute contact with water, lime should be added but sparingly, if at all in the outer joints. When the sand is in the proportion of one or more measures to one of cement, the bulk of mixed mortar will be about equal to, or a trifle less than that of the dry sand alone.

The cement mortar of the Croton Aqueduct of New York, was as follows: for the brick inside lining of the aqueduct, one measure cement powder, two measures sand; for the stone backing, one measure cement powder, three measures sand.

When mortar is to be exposed to dampness only, we may use cement, one; quick-lime, one; sand, four to six parts. The lime should be thoroughly slacked before it is added.

Quantity Required.—A barrel of cement, 300 pounds and 2 barrels of sand (6 bushels or 7 1-2 cubic feet), mixed with about 1-2 a barrel of water, will make about eight cubic feet of mortar sufficient for:

192	square	feet	of	mortar	joints	1-2	inch	thick.
288	"	"		"	"	3-8	"	"
384	"	"		"	"	1-4	"	"
768	"	"		"	"	1-8	"	"

Or, to lay 1 cubic yard, or 522 bricks of 8 1-4 by 4 by 2 inches, with joints 3-8 inch thick; or a cubic yard of roughly scabbled rubble stone work. The quantity of sand may be increased however, to 3 or 4 measures for ordinary work.

Concrete is merely a coarse mortar of lime, sand and gravel or broken stone. Engineers generally apply to it the French name of Beton when cement is used, instead of common lime. When first mixed and deposited, the concrete occupies consider-

ably less bulk than that of its dry materials; but in setting it swells permanently about 1-30 part of its thickness. This last property has been supposed to render it peculiarly valuable for underpinning; but as it also renders the concrete porous and friable, the argument has but little force.

A common proportion among English engineers is 1 measure of ground quick-lime, 1 1-2 of water, and 6 to 8 of gravel. Broken stone is often added, and still better, fragments of brick. Every 1 1-4 cubic yards of gravel makes about 1 cubic yard of concrete. In using concrete, the entire width of the foundation trench should be filled with it and it should be well rammed in layers about a foot thick, as it is deposited.

Gen. Totten, in his work on mortars, gives the following formula for cement concrete, which he used with perfect success where "springs of water flowed over the work continually, and were allowed to cover each days work. The next morning the concrete was always found hard and perfectly set." It was rammed as it was deposited. When not to be rammed he would somewhat increase the proportions of all the ingredients except the stone fragments, to insure the filling of all the voids between these last.

1 1-3 measures of good Rosendale cement powder,
2 measures of sand,
4 " " granite fragments of nearly uniform size and about 5 ounces weights,
1-2 measure of water nearly.

These gave a little more than 4 measures of concrete, or about the same as the granite fragment alone; and each barrel of cement (300 lbs., or 3 packed bushels) made 16 7-10 cub. ft., or nearly .62 cub. yards of concrete: or a cub. yd. of the concrete required 1.61 barrels of cement. The General adds that if one-half of the cement had been omitted, and its place supplied by quick-lime in about the following proportion, the work would still have been very hydraulic, and very strong:

.6 measures of cement,
.4 " " quick-lime,
2.0 " " sand,
4.0 " " granite fragments,
.5 " " water nearly.

The 4 measures of quick-lime to be thoroughly slacked, before being mixed. He also gives the following, as forming a very hard concrete, when rammed :

1 measure good Rosedale cement powder,
1 1-4 " sand,
3 " clean gravel,
33 per cent. water.

Another rammed concrete "became very hard, but was rather too incohesive while fresh, to make the best factitious stone."

1 meas. good Rosendale, Norton's and Saylors' cement powder,
2 measures sand,
3 " clean gravel,
3-8 " (about,) water.

The concrete used on the Croton Aqueduct, New York, consists of

1 meas. good New York cement powder,
3 " clean sand,
3 " hard stone, broken to pass through a ring 1 1-2 ins. diam.

A very good concrete is composed of

1 measure cement powder,
1 1-2 " clean sand,
2 3-4 " gravel,
0.35 (about,) water.

These 5 1-2 measures give about 4 1-2 of concrete.

The following brick-dust hydraulic concrete has been used with success in some important French works :

1 measure quick-lime slightly hydraulic,
1 1-4 " brick, or tile dust,
1 1-4 " sand,
5 " (nearly), broken stone.

These 8 1-2 measures gave about 5 1-2 of concrete. This concrete was impervious to water.

Coignet's beton. The artificial stone which bears this engineer's name has for several years been used in France with perfect success not only for dwellings, depots, large city sewers,

etc., but for piers, and arches. It is composed of 5 measures of sand, 7 measures of finely ground quick-lime, from 1-4 to 1-2 measures of ground Portland cement, (or 6 parts of sand may be used.) These are first well mixed together dry; and then placed in a grinding mill, at the same time sprinkling them with a very small quantity of water so as to moisten them without wetting them. They are then thoroughly incorporated by grinding until they form a tough or stiff mass. It is then put in moulds and compacted with a 16-lb. hammer: slow settling cement is the best; the blocks or slabs will set in from a few hours to a day or more, this depends on the size of blocks that are made. It may be used for foundation walls, piers and arches —and where extra strong construction is required and it is not convenient, or is too expensive to use stone; where there is considerable of this to be done it will not cost more than one-half as much as stone.

Test to show the purity of Portland Cement.

In order to discover whether cement has been adulterated, with blast-furnace slag:—Take 80 grains (Troy weight) of the suspected cement and put into a glass vessel or graduate containing 775 grains of dilute muriatic acid (containing one part of pure acid to four parts of water); the mixture should be well stirred with a glass rod.

Pure cement is not rendered turbid or thick by this treatment. If on the contrary the liquid turns milky, from the presence of sulphur in suspension, while at the same time the yellowish tinge disappears and a strong smell of sulphuretted hydrogen becomes perceptible this is an indication that cinders have been added. The presence of ground limestone, or chalk may be detected in a similar manner by the occurrence of ebullition at the time when the liquid acid is added to the cement. The quantity of adulterated materials, may be approximately found by the amount of ebullition or air bubbles.

Pure Portland cement does not effervesce upon the addition of acid; because it does not contain the carbonate of lime, but is composed chiefly of Lime, Silica, Alumnia, Oxide of Iron, Sulphuric Acid and water.

The proportion of these ingredients vary in samples from different localities; but lime is always about 60 per cent. of the whole, the remainder is composed of the above named ingredients; sulphate of lime should not exceed one per cent. The greatest value is attached in Germany to the presence of magnesia: English and French cements seldom contain one per cent. of this substance, but the proportion rises to 3 per cent. in some German cements.

The most essential points in the manufacture of cements, apart from the tests; are uniformity of mixing, and burning, and fine grindings; without this the material is valueless.

If there is too much sulphate of magnesia in the preparation it will precipitate on the surface of walls, and leave that discoloration so objectionable where it is the intention to retain the color of the brick.

Street Pavements.—In England about 1842 many wooden pavements were laid in every style. The roadways were prepared with sand surfaces, boards laid flat on the surface, and lumber or timber, cut at all angles, with cross-pieces set in. Then again tarred boards were set on edge, and round chestnut and other varieties of woods set on edge, and turned and squared. Planked roads of every variety were made in certain localities. Ten years after most of these had worn out, and been renewed, or they had disappeared. But now the wood is prepared with salts of lime, iron, copper, etc., and coated with asphaltum, and in some localities in London they seem to have come into use again.

Wooden pavements, that were laid of the various patents in New York City have nearly all disappeared. The best appeared to be those coated with asphalt, and set on edge on a wooden board surface, leaving spaces that were filled with gravel. The heavy traffic and wear from the large trucks in New York soon destroys the surface, and keeps the streets in an almost impassable condition in winter. They have not been renewed in New York. In Elizabeth, N. J., and many other parts of New Jersey, where wooden pavements have been laid, they have lasted only from five to seven years. When they are partially

worn out the accumulation of water under them, with exposure to air, and sun, soon rots the the whole surface.

A properly laid Macadamized pavement is decidedly superior, when properly done, to any wooden pavement. All round-wood pavements become uneven after the expiration of one or two years, and are as bad as an uneven cobble-stone roadway.

Some wooden pavements laid in Boston, Mass., seem to have met with better success than in the States of New York and New Jersey. There the wooden blocks were set on edge on a sand bottom six inches deep. Wooden pavements laid of pine or spruce cost on an average $ 2.25 per square yard.

The next kind of pavements that has been used extensively in suburban cities, and some in New York and Boston, are known as asphaltum or bituminous concrete pavements and sidewalks; but the severity of the climate here is such that the frost in winter breaks and injures them to such an extent that they are not considered a reliable pavement as far north as this, although the appearance and surface for walking is so desirable. They cost from $ 2.00 to $ 3.00 per square yard.

Flag-stone sidewalks 4 feet in width are the best for village walks. They average from three to four inches thick. Of course if the width is greater it adds to the expense.

Stone flagging 5 feet wide will average 65 cents per running foot of that width.

Sidewalks with stone curbing, and laid with hard bricks in the various styles, may be laid successfully, where there is a tendency for the frost to raise the surface, by providing a sand bottom of twelve inches in depth; and slushing the surface with a grouting of cement and lime. Roll the surface before it sets, and lay the brick in a grouting of cement. This can be done very fast by ordinary labor, and it has made most excellent work. Have a firm bottom.

Macadamized Roadways—Are usually built by laying down eighteen inches of large stone, blended with fine sand or gravel and somewhat smaller stone six inches in depth. Then on this six inches of ordinary broken stone and gravel, each layer when placed being subjected to a heavy roller, water being freely used. On country roads water is dispensed with.

Artificial Stone Pavements or Sidewalks.—There are several varieties of these in the United States, but they do not seem to stand well when laid as far north as New York City or Boston. They are mostly made of Portland cement, and large sharp sand, in blocks from three to six inches in thickness, and from two to six feet square. The proper method is to lay them on a concrete foundation. Porous material is the best for making concrete, as it allows the cement to enter the pores; all stone and gravel should be wet before adding the cement. One of the best pavements of this kind is the Schillinger artificial stone pavement, and costs an average of 20 cents per square foot. He also makes an asphaltum paving block, laid on concrete. The blocks are about four by twelve inches, and are not affected by the action of frost as ordinary asphaltum pavements are.

New York City, Brooklyn, Jersey City and Newark use the following street pavements:

Belgian Pavement.—This consists of stones, 5x6x6 inches, laid on a bed of sand six inches deep. These vary in size to 4x8x10, set on edge. Cost about $ 3.50 per square yard. They are using on Vesey street, N. Y., a fine paving stone, a kind of moderately soft granite, from the vicinity of Richmond, Virginia. Large quantities of paving stone come from New Jersey, known as Trap and Basalt stones.

Guidet Pavement.—This consists of granite blocks, averaging 12x5x8 inches, laid on six inches of concrete and six inches of sand. It is laid on Broadway, New York, and costs about $5.00 per square yard.

Sidewalks.—The sidewalks in New York City and Brooklyn are laid with blue-stone flagging of various thicknesses, and is brought from quarries convenient for transportation down the North River. Granite flags are sometimes used, averaging ten inches in thickness, and sometimes measure 8 feet by 15 feet. These require no curbing. The blue-stone costs about $3.00 per square yard.

In Baltimore, Boston and Philadelphia brick is chiefly used, cost varying to suit localities, say $ 1.20 per square yard.

Concrete sidewalks are made of a mixture of tar and gravel;

and a concrete of asphaltum cement and gravel is also used, but they do not seem satisfactory for much travel, owing to the action of frost and ice in winter.

Street pavements in Boston are usually of granite blocks, 4x7x8 inches, laid in from 8 to 12 inches of gravel or sand, and cost about $3.25 per square yard.

In Buffalo and Rochester, Medina stone is used; the blocks vary from 2 to 4x8x8 inches, and are laid on 16 inches of sand, gravel or broken stone. They cost about $ 3.00 per square yard, and are very satisfactory.

Method of Calculating Loads on Floors, etc.—Illustrations 44 and 45 show a plan and elevation, representing piers and walls of a structure adjoining another building, or independent. Also show diagrams of loads supported on floors. The base stones are of ordinary size, and generally such sized base stones are used where the load is not important. In buildings that carry an actual load on each floor of say 160 pounds per square foot of floor surface it is best, where the bottom is firm, to lay two bases or footing stones, the first stone to average five feet square, and the second four feet six inches square, with a brick pier built on them, say three feet four inches square, bonded with four-inch flat stone—(blue-stone)—every two feet, and capped with a granite block, ten to twelve inches thick.

It is important that all piers to support inside columns (whether of iron or wood) should have brick and mason-work done in the best manner, with equal joints, and allowed to dry in toward the center of pier before placing the weight of several stories on it, when the load comes direct on the piers. In reference to the load of goods, materials, etc., in stores, after making a calculation of ten or twelve stores, the load in the stores on the first, second and third stories did not exceed 170 pounds per square foot of surface, and above that the load would average from 90 to 100 pounds per square foot of surface. Allow for load on roof for snow, etc., 90 pounds per square foot. In warehouses, such as for hardware, cottons, groceries, etc., the load averaged 260 pounds per square foot of surface. As a guide and a safe rule, the Building Department has, for this purpose, tables of the load on floors, which you will find on page 82.

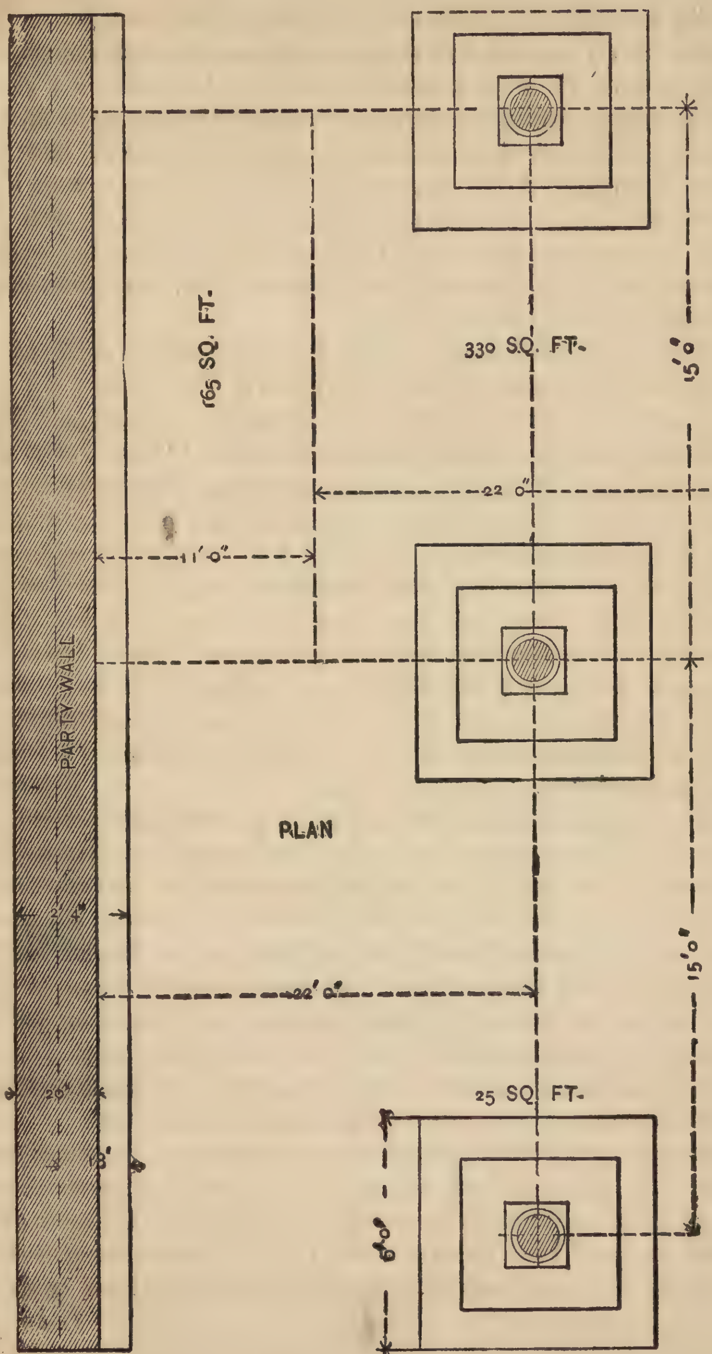


ILLUSTRATION 44.

The average sized piers used for store construction run as follows: For four and five story buildings, where the business done is ordinary, piers average from three to three feet eight inches square, with base stones five feet to five feet eight inches square. Some double stores (fifty-feet front), lately built in New York, have a line of piers in the center, supporting iron columns. These piers are 2 ft. x 2 ft. 8 in. x 10 ft. high, with the first footing stone, 5 ft. 6 in. x 5 ft. x 16 in. thick; the second footing 4 ft. x 4 ft. 6 in. square, by 12 in. thick; these buildings are seven stories or 98 feet high.

The footings and base stones to Stewart's store, Tenth street, New York, did not average above six feet six inches square. This structure is about 130 feet high above the footings. The footings and base stones to the Western Union Telegraph Building, New York, average eight feet square and twelve inches thick, and some parts have inverted arches. This building is 144 feet high from footing stone to top of main cornice, and above this is an iron roof three stories in height. The footings for the Morse Building, Nassau street, New York, are eight feet square, and the piers are five feet square. The walls average three feet four inches thick to second floor. This building is 160 feet high. The Coal and Iron Exchange, Courtlandt street, is constructed on piers and inverted arches on the fronts facing the streets.

In illustration 44, showing piers and walls, the method of calculating the load on floors by the square foot is shown by the diagram. The space from the wall to the center of the pier is figured 22 feet, and from one pier to the other, 15 feet. To ascertain the load sustained on the columns, and on each pier, multiply 15 by 22=330 square feet. This multiplied by a load of 250 pounds per square foot will give a load on each floor, supported by column on pier, of 330 square feet, multiplied by 250 pounds per square foot, equals 82,500 pounds. This load is independent of the weight of materials required in the construction.

Of course every floor has to be calculated, which sometimes shows an immense load resting on the piers. Where wooden girders are used, the piers are placed from ten to twelve feet from centers. When iron girders are used, the piers are usually from twelve to sixteen, eighteen or twenty feet on centers.

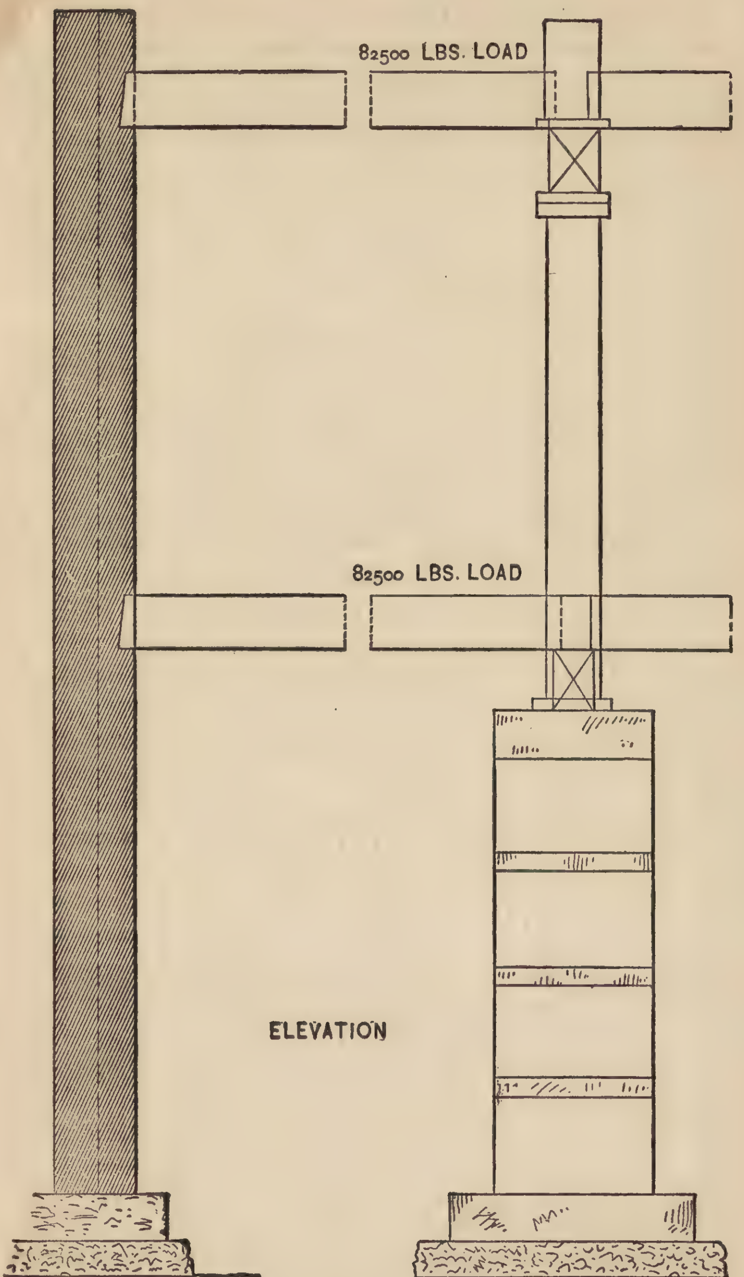


ILLUSTRATION 45.

The load on base stone should not exceed five and one-half tons per square foot of bearing surface on base stones of five feet square, which gives twenty-five square feet. All base stones in and about New York City for good construction have from six to eight inches of concrete for a bed.

It is not unusual with a good foundation to load base stone to piers with from seven to eight tons per square foot of surface.

Thickness of Walls for any Number of feet in Height. —See following table.

When it is the intention to use stone-walls instead of brick, (broken-range work, or quarry-faced range,) add from four to eight inches to the thickness given for brick-walls in these tables.

TABLE OF THE THICKNESS OF BRICK-WALLS FOR STORES, WAREHOUSES AND BUILDINGS THAT REQUIRE EXTRA STRENGTH.

Total height of wall in ft. to be erected.	*Total length of wall in ft. to be built.*	*Thickness in feet and inches.*
		Ft., in.
100	150	3
100	70	2 8
90	150	3
90	70	2 6
80	150	2 6
80	70	2 6
70	150	2 4
70	60	2 4
60	175	2 4
60	50	2
50	160	2
50	45	20
40	150	20
	60	2 4
	55	2
	45	20
	35	20
	30	16

One-twelfth or one-fourteenth of the height of each story is an average for the thickness of a wall.

TABLE OF THE THICKNESS REQUIRED FOR BRICK-WALLS FOR STORES, RESIDENCES, ETC.

Total height of wall in ft. to be erected.	*Total length of wall in ft. to be built.*	*B'sement story in inches.*	*First story in inches.*	*Second story in inches.*	*Third story in inches.*	*Fourth story in inches.*	*Fifth story in inches.*	*Roof in inches.*
100	100 to 125	32	24	24	20	16	16	12
100	80	28	24	20	20	16	12	..
100	45	20	20	16	16	16	12	..
90	100 to 125	32	24	20	20	16	16	..
90	70	24	20	20	20	16	16	..
90	45	20	20	20	16	16	16	..
80	100 to 125	28	24	20	16	16	12	..
80	60	20	20	16	16	16	12	..
80	45	20	20	16	16	12	12	..
70	100	24	20	16	16	16	..	12
70	55	20	16	16	12	12	..	8
70	40	20	16	16	12	12	..	8
60	100	20	20	16	16	12	..	8
60	50	20	16	12	12	8	..	..
60	30	20	16	12	12	8	..	..
50	100	20	16	16	12	..	..	..

In using the above tables for thickness of walls in Baltimore, Philadelphia, Washington, etc., the walls average more in proportion, owing to the brick being larger than in other parts of the United States. Use for eight-inch walls 8 3-4 inches; for twelve-inch walls, 13 inches; for sixteen-inch walls, 17 1-2 inches; for twenty-inch walls, 21 1-2 inches; for two-feet walls, 26 inches, etc.

Footings are twice the thickness of basement walls.

All divisions on party walls between dwellings should be at least twelve inches. When the walls are eight inches the wood beams of floors for each side, cut through them.

THE ART OF PREPARING FOUNDATIONS,

WITH PARTICULAR ILLUSTRATION OF THE

"METHOD OF ISOLATED PIERS,"

AS FOLLOWED IN CHICAGO.

BY FREDERICK BAUMANN, ARCHITECT.

Revised by G. T. POWELL, A. and C. E.

WITH NINETEEN WOODCUTS.

The art of constructing foundations comprises two distinct but interdependent parts: FIRST, *the art of treating the ground;* and SECOND, *the art of building the base.*

FIRST PART.

The Art of Treating the Ground.—All ground from the nature of things, is *compressible*—will yield under pressure. This is owing to three different natural causes; FIRST, *general compressibility of matter*, which is so slight that in practice it causes no concern; SECOND, *imperfect packing of the constituent parts and incipient fluidity*, which induces to study and care, though positive artificial treatment be not needed; THIRD, *semi-fluidity*, which in most cases calls for positive artificial treatment. Accordingly, I shall consider the different building-grounds under the head of three distinct classes: *solid grounds, compressible grounds, semi-fluid grounds.*

Class I.—Solid Grounds.—This class comprises *rock, gravel, dry sand*, in their natural beds, and of sufficient thickness of strata. The treatment is very simple, and in most cases alike. Excavations must be made to remove loose deposits and expose

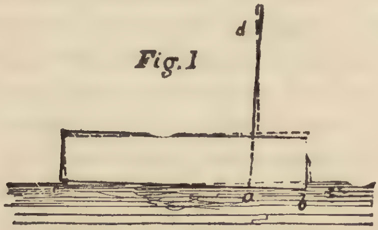
the *natural bed.* Surfaces must be made *level,* because bases should not be started upon inclined planes. In this manner the most common engineering routine will ever attain good results as to foundations. The ground being, for all ordinary practical purposes, next to incompressible, differences in the weights of the various parts of the superstructure produce no manifest defects. Neither is there any considerable manifestation of piers or corners deviating from the line of the perpendicular, though, perchance, such piers or corners were not centrally supported. Concrete or no concrete, inverted arches or no inverted arches, *random work* or *work rightly considered,* the result is practically ever the same; the slight deviations from the true lines, which may occur, pass unnoticed; the builder has nought to think on the subject; his common every-day routine suffices him in all his cases, and he remains in ignorance as to the proper principles by which the true art of preparing foundations is governed. Their practice was upon ground of the first class, which prevails in most of the large cities of the country, and taught them nothing to the point; nor could they avail themselves of the experience of others, inasmuch as, beyond this present treatise, there is (as far as at present known) nothing in print even pretending to give information. The evolution of the "method of isolated piers" is but the result of modern wants as to the construction of mercantile buildings.

Class II. — Compressible Grounds.— This class comprises *clay* and *watery sand,* and mixtures of the two, a whole scale of grounds, from the border of the first class downward to semi-fluidity. The successful erection of any ordinarily heavy structure upon such ground involves the consistent application of two well known (and often, though loosely mentioned) principles: FIRST, *the areas of base must be in proportion to the superincumbent loads;* SECOND, *the centers of these areas of base must coincide with the axis of their loads.*

These principles are self-evident, well known, and often loosely mentioned, yet so seldom observed. It is indeed, needless to prove that ten square feet of bearing surface, *cæteris paribus,* will bear more weight than will two square feet, or four, or nine. It is superfluous to specially make clear the fallacy of placing

the axis of any load upon or near the edge of a base, or in any measure away from its very center. The natural result of such foolish proceedings would be that, as the ground yields, the base assumes an inclined position, and the axis, which must retain its original angle with the base, is thrust out of its perpendicular line, as represented by Fig. 1. It is not then these

Fig. 1



simple principles that will occupy me; it is rather their varied and manifold application in the practice of this difficult "*art of building*," in which *economy*, rightly understood, is a principal factor, nay, in fact, *the* factor, which really renders it a science, which can only be attained by one who has acquired a manifold experience, and who previously has had such a discipline of mind as to enable him to systematically collect, and assimilate with himself, the mental fruits of his labors.

First Rule.—*Resolve the building, upon its ground plan of the lower story, into isolated parts, and independently apportion to each its proper share of foundation.* The first part of this is of old standing, and often applied in exceptional cases—for instance, a church with a massive tower. But the mere keeping the tower separated from the other parts is of no avail, unless the latter part of the rule is observed, by special intent or by chance of circumstances, as the case may be. It is this matter of resolving a complex building into isolated parts, a task requiring experience and sagacity. Scarcely are there any two buildings alike in this respect, and the question ever arises, where shall I stop? With some buildings it may be simple, so that the old every-day routine may suffice.

Second Rule.—*Estimate the weights of all those (really and ideally) isolated parts, in order to apportion to each its due share of foundation.* To this end it is required to know the *bearing capacity*

of the particular ground, and also whether or not, and in what ratio, the load may be increased in proportion to the area of base. If it were found, for instance, that the medium bearing capacity (reduced to a convenient unit) is, say two tons per square foot—meaning that under such proportionate load the ground will be compressed in a limited known ratio—and if it were further known (approximately so at least) that this ratio holds good for any amount of load, the task is at once simple. A pier weighing 120 tons must receive a base pressing upon an area of 60 square feet; a pier weighing 20 tons must press upon an area of only 10 square feet, and so on in this proportion. It will be found, however, that the proportion varies with the nature of the ground. Ground least fluid and most solid (dry clay) will thus give too much support to the lesser loads; ground approaching semi-fluidity will give them too little. In each case, therefore, where the properties of the ground are not fully known in advance, tests must be instituted for their ascertainment, and the apportionment made accordingly.

Third Rule.—*Determine, upon the ground section, centers (and center lines) of all (isolated) parts, which in upright section will be the axis (and axial planes) of these parts, and place the (masonry) bases so that the centers of their areas of contact will coincide with the first centers.* It means that foundations must be made to support their loads *centrally.* The observation of this rule is of the utmost importance, for upon it will depend the perpendicularity of all the walls and the corners of the structure. Let all parts have central foundations, and no inherent tendency will exist to disturb this perpendicularity. There will in such case be no particular need of any anchors, except for temporary use, while in the contrary case the strongest and best applied anchors will not suffice to preserve the *exact* normal position of the walls and corners. *Have the bottom right, and all else will come right without many further precautions.*

I comprise the above three important rules under the head of "Method of Isolated Piers," which I advance as a *scientific method* in opposition to the old *random method of continuous foundations.*

I am aware that *isolated foundation-piers* are of old date.

Such isolation of piers has been, however, the *exception,* not the *rule.* Its origin is from chance and circumstance, not from logic. I, on the other hand, advance a principle which makes *isolated piers* the *rule in all cases*, and *continuous foundations the exception,* where, for instance, piers of *uniform weights* are so close to each other that the bases will interconnect.

Objection might be raised to this new method, on the ground that any building-ground may not be everywhere of the same uniform density. This circumstance will but seldom occur, and if and wheresoever it does so, the greater difficulty should be a spur to greater care and perseverance. It would in such case be requisite to make the most careful survey of the ground, to determine the degrees of variations in density, and map the same, in order to obtain a correct basis for estimation and apportionment.

The Building-ground of Chicago.—The subsoil throughout is of blue clay, covered by sand and loam, which, below the level of ground-water, become "*quicksand*" and "*blue muck.*" In the central part of the city the clay is found at a depth of about five feet from the original surface, which now is about eight feet below the established grade of streets. This clay-bed is more or less permeated by water, which enters through a network of fine gravelly veins, and through the river channel; it is, therefore, varying in its bearing capacity in proportion to its state of humidity, the driest clay of course being the hardest, and therefore the best for purposes of foundation. In the central part of the city the clay-bed has a distinct surface, covered with a scattered stratum of boulder-gravel, and is termed "*hardpan.*" It approaches the surface to within five feet. Throughout the West Division the clay is equally near to daylight, though it has no distinct surface, the loam gradually changing into clay.

From State Street eastward, the dip of the clay-bed is so steep that already within one block it becomes ordinarily impracticable to reach it. Nor is this necessary, for the overlying soil answers all purposes. This soil is here an intimate mixture of clay and fine sand, in common parlance termed "*blue muck,*" on account of its shifty nature; but its quality as building-ground

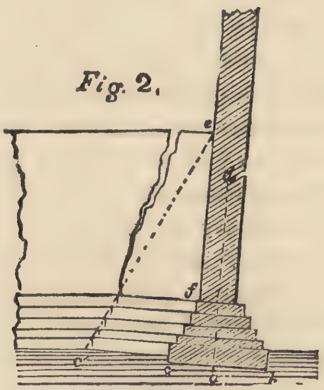
is better than first appearances would warrant. Toward the North and South the clay is covered by a bed of fine sand, which grows in thickness with the distance from the center of the city; it becomes what is termed *quicksand* from the level of ground-water downward, which level is mostly within a few feet from the surface. *A massive stone church tower erected upon this quicksand gradually sank, within about eight months after its completion, some twenty inches, carrying with it the surrounding ground on a radius of over forty feet. There being apparently no limit to this "settling," the tower was taken down. Its weight upon the base was probably not over thirty-six pounds per square inch.*

The convenient bearing capacity of all this soil is *twenty pounds to the square inch.* With this the bases in all ordinary cases become not so widespread as to necessitate for their solid construction any cutting into the hardpan. Such proportionate load will compress the hardpan to the extent of about one inch during construction of the building, and about one-half of an inch during the next six months following, after which time the load appears to be poised upon the clay; the season, as often the popular belief is, having no share in this "settling." The compression will be greater, as a matter of course, upon the softer portions of the clay, as well as upon the loam, dry or wet; it is least upon the dry surface-sand, where this can be made available. All that is necessary is the strict application of the "method of isolated piers," so that all parts of the ground will be compressed in the same degree, causing a perfectly equable "settling." But in practice it will ever be found advisable to base calculations upon the smallest possible amount of ultimate compression, and to be guided in this matter (as we ought to be in all others) by prudent *economy*; hence I term the bearing capacity stated a *convenient* one. This matter of dividing a building into isolated parts, and estimating the weight is by no means as simple as at first it would appear, and may even in some cases offer material difficulties. Take, for instance, a building six or seven stories high, fire-proof, with fire-proof vaults in the lower stories. The outer and some of the inner walls are of full height; other inner walls are one, two or five stories less in height; some of the vaults extend through four stories, others stop in the base-

ment; the loads become shifted by the location of the openings: there are columns bearing floors; the internal walls and columns do not become loaded as the building progresses, for floors, ceilings and plastering are not applied before the building is roofed. Now if the ultimate "settling" is kept within the limit of one and a half inches, as it ought to be, the problem of attaining a sound and perfect structure is solvable through an ordinary amount of sagacity and carefulness applied upon the "method of isolated piers;" probable differences falling within the limits of one-quarter to one-half of an inch, and causing no palpable defects.

Examples and Instances—*Being an Illustration of the "Method of Isolated Piers.*—Fig. 2 shows upright section of a pier of an outer wall, and elevation of an abutting dwarf-wall. If, as the old method would suggest, in order to furnish "all the bearing possible," the dwarf-wall is connected with the pier at its line

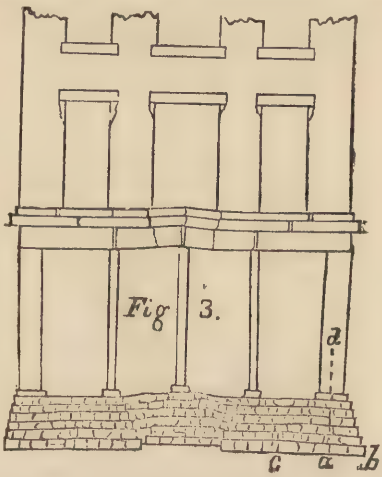
Fig. 2.



of intersection, *e f*, the pier will be thrust outward, and the dwarf-wall crack as indicated. The cause may readily be found. Construct the axis, *d a*, of the pier, and see whether it coincides with the center of area occupied by the base of the pier. Were the dwarf-wall *not connected* at *e f* and *a b*—*a c*;—i. e., were the construction made in accordance with the "method of isolated piers," there would be no thrust against the pier. But the usual old random mode of "all the bearing possible" extends the area of base inward to *c′*, and thereby shifts the axis of the

pier *off the center* toward the outer edge of the supporting base, *b c'*, which causes the ground to be pressed into an inclined surface and, consequently, the pier to be thrust outward. Were the base of the dwarf-wall made so narrow as to cause a settling of the dwarf-wall equal to that of the pier, it would at first sight appear as though then the wall might be connected. Yet this is, nevertheless, forbidden by the circumstance that the base of the dwarf-wall would receive *all* its load before the pier would; say, one-fifth part of it. Besides, it is extremely difficult to proportion so slight a load with sufficient accuracy; and the laws of nature are very severe; but a slight deviation of the axis, *d a* from the center of area of base will have its marked effect. Two rules may be abstracted from this instance.

First—Let the axis of the load always strike a little way



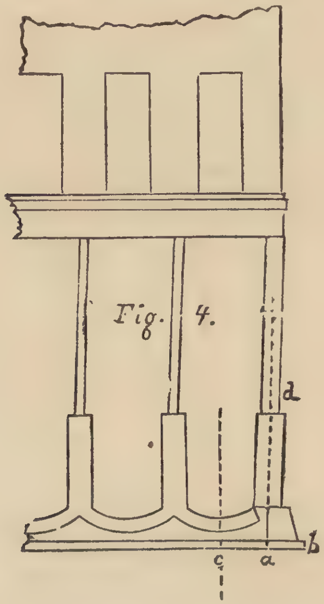
inward from the center of the area of the base, in order to make sure that it will not be toward the *outside*. Any inward inclination of the pier is rendered impossible by the floor beams, while an outward inclination must be counteracted by artificial means, such as anchors, which, in all cases, are but reliable to a certain degree. Anchoring is thus reduced to safeguards; although anchors are placed on every sixth or eighth beam of each tier on stores.

Second—*Never connect an abutting dwarf-wall with an outer pier or wall.* Build it independently, with a distinct, clean,

straight joint. In some cases it might be advisable to leave four inches of clear space, to be walled up afterward.

Fig. 3 shows what, in a measure, occurs to an old-fashioned four-story building erected upon continuous foundations. The middle column, having no load to sustain, retains its original position while the others are pressed downward, with results as represented.

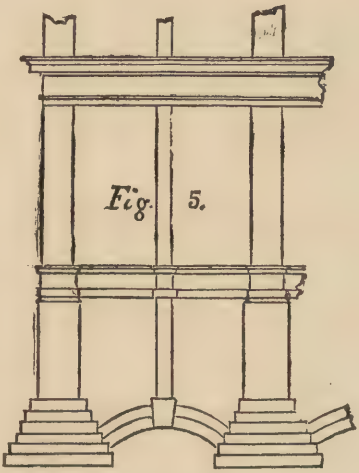
The corner piers, if not prevented from doing so by the resistance of buildings at the right and left, are thrust outward



because their axes are not centrally supported, as can be readily seen without further explanation. The foundation, in fact, resolves itself into piers, but in a manner contrary to sound engineering, giving to the lightest pier the largest support. Before the great fire, scores of similar fronts were seen in Chicago, nor has the lesson been thoroughly understood after this great event.

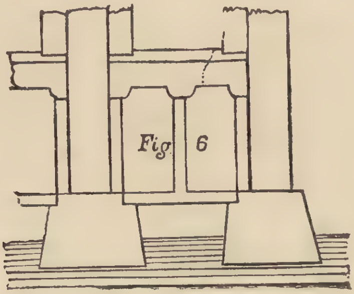
Years after the "method of isolated piers" had slowly taken its course, some new comer of an architect took it upon himself to show his colleagues that he could overcome the difficulty by means of *inverted arches*. The result was a building on the

corner of Washington and Dearborn Streets, as here represented by Fig. 4. The extent of the front was forty feet; the lintel was one piece of timber, connecting the piers and columns of the front, causing all to incline, parallel with the corner pier, to the extent of nearly three inches out of their perpendicular lines. It is not difficult to conceive that good inverted arches have a greater effect upon shifting the axis of load off the center of base than has a mere continuous foundation (or a continuous bed of concrete); likewise, that the thrust of the arch itself, if any such occurs, would have the tendency to *counteract* rather than enhance the difficulty arising from oblique settling of the base.



The case grows serious with Fig. 5, which represents part of a front, consisting of alternate heavy and light piers. Continuous foundations, or beds of concrete, or inverted arches, would have a tendency to thrust the corner pier outward, and to break the horizontal connections over the little piers, as has been demonstrated by the former examples. But even the smallest admissible bases might prove troublesome in regard to the little piers. In such cases, resort may be had to an entire omission of bases for such little piers, and to the introduction of some bearing connection from large to large pier for their support, as shown in Fig. 5. A case has occurred very lately in Chicago, where the bases of such heavy piers were made too small, and

those of the lighter piers too large (isolated piers were here employed without method). The effect was that the sinking heavy piers hung themselves, with part of their weight, by means of very stiff horizontal connections, on the little piers, and literally crushed them. Had these crushed piers been stronger than the horizontal connections, the latter would become seriously damaged. As it was, the building underwent jack-screw operation and insertion of new piers. In cases where there are mere mullions in the larger lower windows, as represented in Fig. 6, if the mullions are supported on iron



construction from large piers on each side, piers under will not be required ; otherwise, direct foundations under these mullions will be necessary, and the piers to be proportioned to sustain the load above.

A prominent building lately erected with such mullion piers upon direct foundations was merely saved by the fact that, *firstly*, it was placed upon old, well settled foundations, and, *secondly*, that the three upper stories of the design were omitted, leaving the building, as it now stands, four stories high. The consequence, thus far, is the mere fracture of one of the powerful stone lintels covering the basement openings (as indicated by dotted line).

The case assumes a different aspect under Fig. 7, yet it is readily shown to belong to the same class. In 1852, I constructed the front of a blacksmith's shop in the manner shown by Fig. 7, with this result, that the keystone of the doorway arch dropped downward. The inverted arch owed its existence to the universal random idea of "get all the bearing you can."

But when the piers *e f* and *g h* are considered by themselves, it is not difficult to observe that, through the very introduction of this inverted arch (or continuous rubble wall or concrete), the axes of these piers become shifted off the centers of their bases, and, consequently, thrust outward; hence the dropping of the

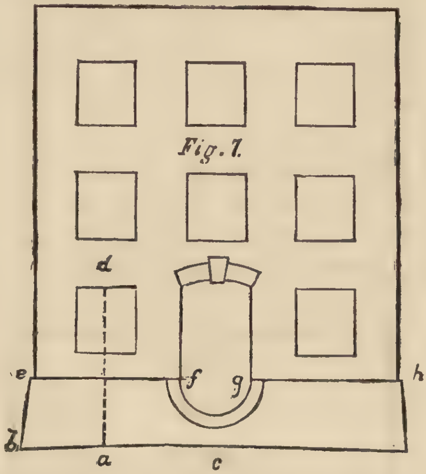


Fig. 7.

keystone. The fact is, that a front thus constructed compresses the ground under its base to a *convex* plane, while on the other hand, by the principle demonstrated in the discussion of Fig. 2, it should be so constructed as to compress the ground to a plane slightly *concave*, which may be readily effected by omitting the foundation under the opening.

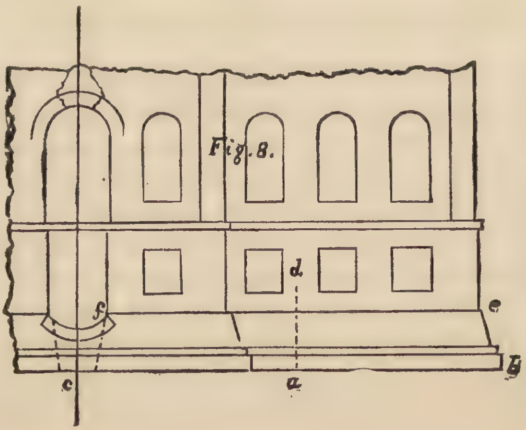
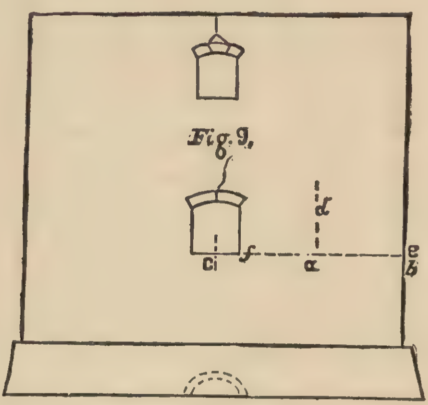


Fig. 8.

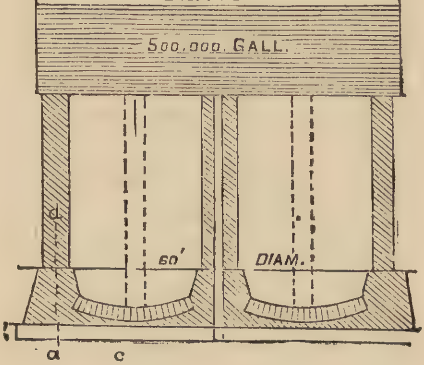
The reader will now fully understand the reason why the arches over almost all large openings (in churches etc.) have more or less parted. He will understand from Fig. 8 why the arches over the center of the ill-fated Court House wings were rent. The law acts with unerring certainty, no matter what the extent of the front, no matter how slight the cause. But to furnish a most striking example of the minuteness with which this law operates, I produce Fig. 9, which is intended to represent a view of the east gable of the (destroyed) celebrated Crosby Opera House. The foundation wall, twelve feet high, was built of rubble stone in cement mortar, and had ample time to set, since the brick wall was not started thereon until about two months afterward. The base was five feet wide upon the hardpan, the brick wall twenty inches thick for twenty feet high,



and sixteen inches for the following sixty feet. The load upon the base was consequently about twenty-six pounds to the square inch. The whole weight of wall and base was 850 tons, less twenty tons omitted by the two openings. The ultimate settling of the wall could not have been over two and a half inches, yet the slight reduction of the load by only twenty tons, at its center, from the total load of 850 tons, caused the base to assume a slightly convex plane, so that both corners were somewhat thrust over, as indicated by the parting of the arches over the openings, which parting was so decided that the cracks were plainly seen at 160 feet distance, from the opposite side of

State Street,* and caused a whisper among the unsophisticated passers by to the effect that the house was unsafe. And all this from so little a cause! The most remarkable feature of this case, however, is that the base, *thirty-two feet thick,* as it were, from the hardpan to the sill of the lower opening, did accommodate itself readily to the assumed curvature of the ground; that, in fact, all this mass of solid brick and stone work acted as though it were possessed, in a measure, by a minute degree of

Fig. 10



quassi-fluidity. This ought to show to satisfaction, if not a proper consideration of the case by itself did, that compressible ground cannot be spread over at random by concrete, or any kind of masonry, and thereby made exempt from the operations of the "law of convex deflection." All such masonry, of whatsoeverkind, will, from its nature, yield and accommodate itself to such curvatures of the ground as the different loads at different places will naturally produce.†

To give one of the most flagrant instances of what happens from non-observation of the biddings of the "law of convex deflection," I introduce (Fig. 10) a section of the old water-reservoir structure on Adams Street, erected 1854. The consequence

*This gable was a mere court wall, receding ninety-three feet from the line of State Street, upon which, immediately afterward, a fine building was erected by the owner of the Opera House.

† Omitting some of the base at the center, by means of an arch as indicated, would have preserved the exact perpendicular state of the corners, so as to leave the arches intact.

was the immediate discomfiture of the structure on the first day when the water was let on. Even if other causes had not enhanced this result, the "law of convex deflection" alone would have been sufficient for its production. To render the concern serviceable, all openings were walled up and an intermediate inner wall was built, as indicated by dotted lines. Nothing could have happened had the foundation been prepared in accordance with the "method of isolated piers."

Cross section through an outer wall.—Fig. 11. It will

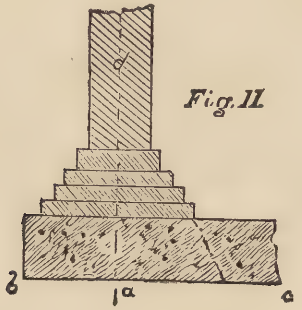
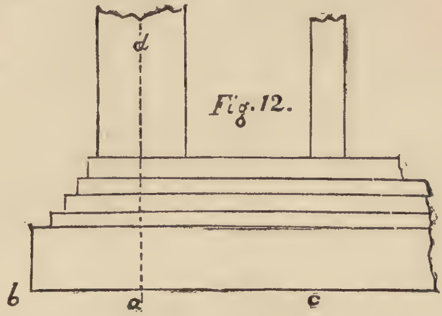


Fig. 11

readily be perceived that, by dint of this continuous bed of concrete, the axis $d\ a$ is shifted off the center of its base; the clay beneath will consequently be compressed to a *convex plane,* with a tendency to thrust the wall out of its perpendicular line. This tendency need, however, not become realty, because of the very probable rupture of the bed of concrete, as indicated in Fig. 11, or else because the cross anchoring will be so effective as to prevent such occurrence to an extent that will be noticed by a non-expert. Had this wall an independent central base, as dictated by the "method of isolated piers," no possible contingency could ever arise.

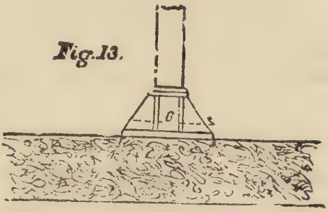
2. Considering the large inequality of the weights of the piers of the outside walls, the heavier piers will sink down, in some measure, proportionate to the weight of pier and size of base upon the clay, such as it may assume for itself, while the little piers will almost wholly retain their original levels. The difference may possibly not be very considerable, and escape the eye of the non-expert, but occur it must, by dint of inexorable law.

3. Taking a view of a corner with adjoining pier, Fig. 12, the case represents itself similar to what it does in Fig. 11, with this difference, however, that in Fig. 11, the concrete is bare and



may be readily ruptured, while here the concrete is strengthened by a mass of the most excellent masonry, and may not break so as to save the corner from being thrust outward. Besides, the anchors, as usually applied, get no hold at the corners. To hold

Fig. 13.

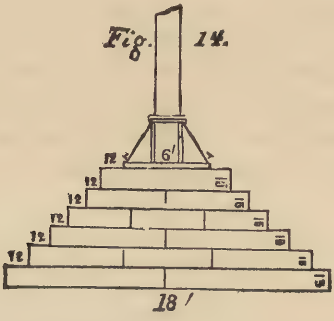


them would require a longitudinal and cross anchoring within the thickness of the walls, from corner to corner, a troublesome and expensive proceeding. Under the "method of isolated piers," with observance of the biddings of the "law of convex deflection," the corners would take care of themselves without anchors.

4. Taking a section through one of the intended internal piers, Fig. 13, the case assumes a very serious aspect. The load per column is said to be upward of 380 tons; the column is to stand upon an iron stool, with bottom plate six feet square, bedded on the bare concrete. To arrive at any accurate, or even approximate, estimate of the efficacy of this bed of concrete, under existing circumstances, is simply a matter of impossibility. A mechanical estimate to this effect requires a knowledge of its

exact absolute and crushing strength, as well as ot the exact degree of the elasticity and incipient fluidity (yielding property) of this concrete. Even if these properties were ascertained from samples, it would by no means follow that the bed, just at such particular place, is altogether precisely according to the samples. Trials have been made by loading plates one foot square with as much as thirty and more tons upon each. To conclude from this trial upon the nature of the case is, I believe, a fallacy. Even if one square foot would bear, without damage to the integrity of this bed of concrete, say 100 tons during a week, the conclusion is by no means warranted that it will carry *for all*

Fig. 14.



time to come 380 tons upon a spot six feet square, with absolute and infallible certainty. (Actual practical judgment, with an allowance of one-quarter of the load that produces any movement of depression on the earth, will be safe.) The load, as the case is, must be trusted on *chance,* instead of on mathematical certainty, and is, therefore, in a technical meaning *insufficiently supported,* which involves by no means a prediction that in reality the support *will,* or *must,* fail. It simply means that it *may* fail. Any construction in building that is not secure by dint of mathematical certainty, is technically insecure, and therefore condemnable. How differently does this case present itself under the light of the "method of isolated piers," as is illustrated by Fig. 14. Here the hardpan is loaded to a ratio of about twenty pounds to the square inch. With a pier well bedded, and securely constructed out of the most beautiful material so readily at hand in Chicago, it is mathematically certain that the ultimate "settling" will be (about) one and a half inches. Be-

sides, this construction would have the point of economy in its favor.

Concrete.—Good concrete is always made up with cement-mortar. This artificial conglomerate rock is spread upon the building-ground at large, or upon the bottom of foundation trenches, in a thickness varying, as the case may be, from one to five feet for the purpose of an "*equalizer*." Concrete work at best is *random work*, that may and may not do good service. Upon hard and practically incompressible ground, it is superfluous, as a matter of course, except what may be required for the bedding of footing courses. Upon compressible ground it will, *under some circumstances*, accommodate itself to the deflections of the ground caused by superincumbent loads, and thus may, if circumstances concur, be of *very serious damage* to the structure, under the "law of convex deflection," as before demonstrated. I reject *random work* as being contrary to the spirit of the present age, and recommend in its place the "*method of isolated piers*" for foundations.

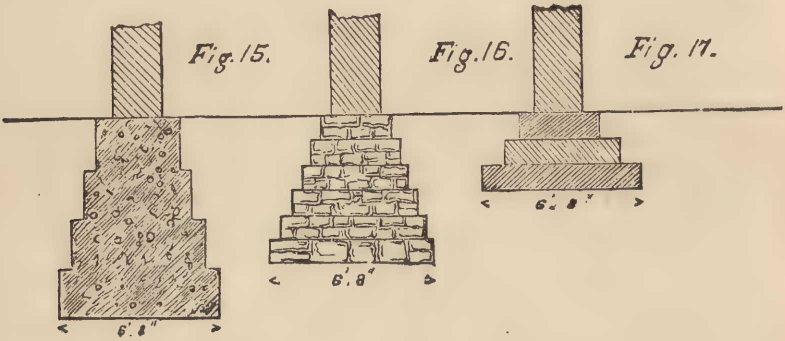
Concrete is applicable in foundations as a *base* in place of other masonry. Its application is there justified in all cases, where it chances to be the *cheapest* material. It is in this sense one of the means at the hands of the engineer for the attainment of his ends.

Class III.—Semi-Fluid Grounds.—This class comprises *silt*, *marsh*, *peat*, and the like. When gravel or rock can be found within practicable distance, piers of some kind may be sunk upon it; but ordinarily resort is had to artificially condensing the ground by means of *piling*.

SECOND PART.

The Base is alike a means of *support* as it is a means of *spreading out* in order to convey the pressure exacted by the load upon such area of the ground as has been determined under the "method of isolated piers." The base therefore must be in every respect *solid;* the pressure to which it is subjected

must in no way move its constituent parts. The Chicago material for bases is: *Dimension stone*, hard lime-rock, of most any dimensions, from eight to twenty inches thick, and with even beds. There can be no better material in the whole world than this dimension stone. There is also *rubble stone* of the same rock, hard, flat bedded, handy as to size. Concrete, being inferior to rubble work, and besides being more costly, is out of the question, at least under a reasonable view of employing means to an end. For dimension stone I have adopted the rule



of making the offsets somewhat less than the thickness of stone, though I know of no instance of an evil result from offsets being even more than equal to the thickness of stone. For rubble I have adopted four inches of an offset to each foot of height. For concrete I should reduce the offset to three inches. Figs. 15, 16, 17 represent bases accordingly, all under the supposition that the weight of the wall requires a width of base of six feet eight inches.

For Dimension stone	$6.90	per	foot	lin.
" Rubble stone	6.90	"	"	"
" Concrete	14.28	"	"	"

making evident the absurdity of employing concrete in Chicago foundations.

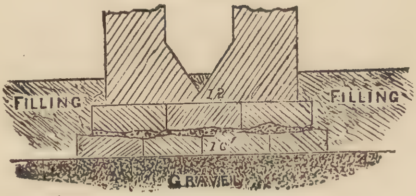
The money point grows more in favor of rubble stone as the base is narrower, and more in favor of dimension stone as it is wider, as can be readily estimated.

Pier bases ought in all cases to be wholly constructed of dimension stone.

The *bedding* of the base on the ground offers but little difficulty. Upon sand and loam, dry or wet, it beds itself without trouble. Clay is best covered first with a thin layer of gravel or broken stone, rammed into the surface, and grouted with liquid cement-mortar. A layer of concrete, from two and a half to four inches thick, and rammed partly into the surface, answers the same purpose. Upon the surface thus prepared mortar is spread, and the stone bedded.

The *mortar* ought always to be good cement-mortar, with sand of very coarse, gravelly nature as its component. For joints of two or more inches in thickness, between dimension stones which happen to have uneven beds, a mortar, made of two parts of roofing gravel and one of fresh cement, has answered excellent purpose. By this the expense of dressing the stone is saved, and yet the end attained with all the certainty required in ordinary cases.

Fig. 18.

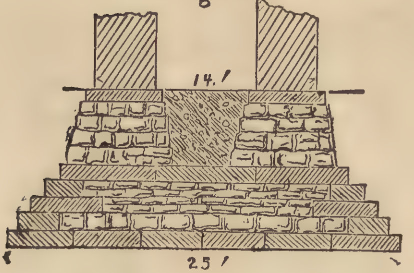


I conclude the subject with Figs. 18 and 19, representing bases of two of the tallest chimneys in Chicago.

Fig. 18 is the base of the chimney erected in 1859 for the Chicago Refining Company, 151 feet high, 12 feet square at foot. The base, merely two courses of heavy dimension stone, as shown, is bedded upon the surface gravel near the mouth of the river, there recently deposited by the lake. The mortar employed in the joint between the stone is roofing gravel and cement. The area of base is 256 square feet, the weight of chimney, inclusive of base, 625 tons, giving a pressure of thirty-four pounds to the square inch. This foundation proved to be very perfect.

Fig. 19 is the base of the chimney erected in 1872 for the McCormick Reaper Works, which is 160 feet high, 14 feet

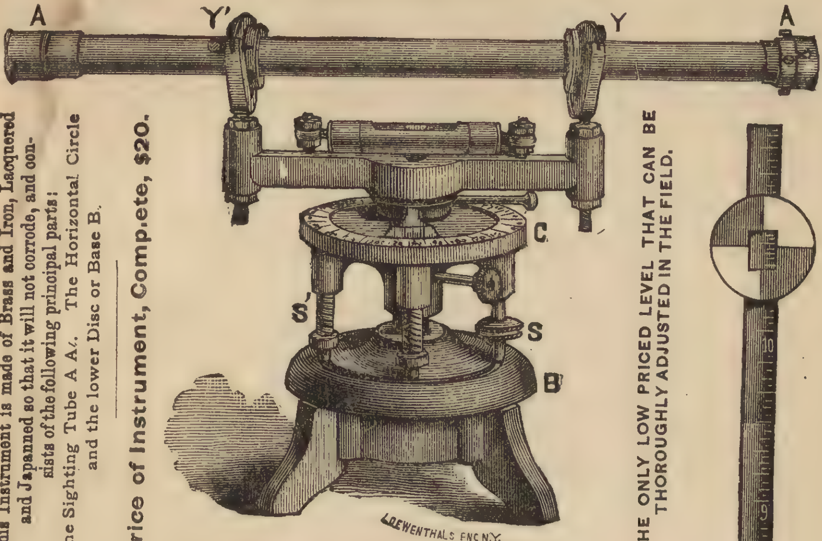
Fig. 19.



square at the foot, with round flue of 6′ 8″ diameter. The base covers 625 square feet: the weight of the chimney and base is approximately 1,100 tons; the pressure upon the ground (dry, hard clay) is therefore, 24 1-3 pounds to the square inch. This foundation too proved to be most perfect in every respect. 24 1-3 pounds per square inch is a moderate load for piers.

AN IMPROVED LEVELING INSTRUMENT.

Adapted to the use of Architects, Engineers, Masons, Builders, Farmers and others.



This Instrument is made of Brass and Iron, Lacquered and Japanned so that it will not corrode, and consists of the following principal parts: The Sighting Tube A A'. The Horizontal Circle and the lower Disc or Base B.

Price of Instrument, Complete, $20.

THE ONLY LOW PRICED LEVEL THAT CAN BE THOROUGHLY ADJUSTED IN THE FIELD.

DESCRIPTION OF THE LEVEL.

THE sighting tube AA' is 14 in. long and has at the end A' a pin hole looking through the tube, and at the other end A a small ring inside the brass shield or outer ring shown in cut holding the cross wires. A cover is provided as shown in cut to protect the cross wires. This tube rests in the Ys, Y and Y'. On this tube at the Ys are two rings with flanges, like car wheels, and it is held in its place by the latches on the top of the Ys. By loosening these latches this sighting tube may be revolved to test the adjustment of the cross wires.

At the feet of the Ys will be seen the nuts, one above and one below the end of the cross bar, which may be turned, thus raising or lowering the end of the tube and adjusting the line of sight to the line of level. The circle C is graduated to 10° and the pointer marked to degrees, so that the instrument may be used in laying off angles, squaring foundations, &c. The pointer is movable and can be fixed in position by the set screw shown in the cut just below the cross bar. The cross bar carries the glass bubble which is seen in the cut. The bubble itself may be adjusted by the screws. To the circle are attached the two thumb screws and springs opposite to them by means of which the instrument is brought to a level.

In the outer edge of the Base B is a smoothly turned groove in which the feet of the screws and springs may slip easily whenever it may be necessary to revolve the circle on the base. The centre of the base is formed into a socket for the ball referred to above. The under surface has a solid cylinder which screws in the collar of the tripod. The cord suspending the plumb-bob drops from the centre of the instrument to which it is attached by a loop not shown in the cut. From this description it will be seen that this instrument can be *adjusted* in every way possible in the highest priced instruments, and has besides the additional feature of a horizontal circle, making it in reality a plain transit, as well as level.

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